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Reproducibility of surface roughness in reaming

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Technical report

Reproducibility of surface roughness in reaming

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2011

Manufacturing Engineering
Department of Mechanical Engineering
Technical University of Denmark

Foreword

Part of the data obtained in this report come from experiments performed during a course Manufacturing Tribology - Modelling and Testing at Technical University of Denmark (DTU). This report is also a part of an on-going research on metal cutting activities at DTU.

The Authors wish to thank Ditte Bangsgaard Kjeldsen for performing micro hardness and some of surface roughness measurements, Rene Sobiecki for making reference 2D and 3D measurements and Lars Peter Holmbaeck for assistance with machining setup.

Kgs.Lyngby, 2011

Pavel Müller

Abstract

An investigation on the reproducibility of surface roughness in reaming was performed to document the applicability of this approach for testing cutting fluids. Austenitic stainless steel was used as a workpiece material and HSS reamers as cutting tools. Reproducibility of the results was evaluated with respect to different operators, workpieces and measured position in the reamed hole for different combinations of lubrication condition and cutting speed. The measurands were the conventional surface roughness parameter, Ra and the ability of a cutting fluid to ensure a surface which is a replication of tool geometry and path. 2D and 3D reference measurements were done to ensure traceability of the measurement. Moreover, surface profiles were examined under the 3D optical microscope. Measuring uncertainty evaluation using statistical methods was applied.

Surfaces produced with a low cutting speed were generally reproducible when considering different operators, workpieces and measured position in the hole, unlike the surfaces produced with high cutting speed. These latter contain uneven, random surface profiles and vary considerably for different operators. However, it can be observed that a higher concentration of the oil in water-based cutting fluid (or when using a straight mineral oil) results in surface profiles that are more reproducible at higher cutting speed. Moreover, it can be seen that three cutting fluids (two water-based cutting fluids with different oil concentration and a straight mineral oil) used in connection with a low cutting speed result in "identical" surface profiles.

Biggest uncertainty contributors were due to the process repeatability and repeatability around the hole circumference. This was however only in the case of high cutting speeds and low degree of oil concentration. High reproducibility of different operators, especially when low cutting speed was applied, was achieved. From the surface profiles, an identification of individual feed marks from the tool is possible, tool replication being most clear from the 3D reference measurements.

Aim of the work

The general aim of this work was to investigate reproducibility of surface roughness in reaming austenitic stainless steel with HSS reamers. Specific aims were:

1. quantify tool replication in reaming as a more precise way of addressing the effect of lubrication on surface roughness;
2. analyze the surface profiles from different operators, workpieces, measured position on the workpieces, cutting speeds and cutting fluids;
3. obtain high reproducibility as a step to accredited testing.

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Chapter 1

Introduction

Reaming process is widely used cutting operation in industry. Reaming tests belong to processes which are used as laboratory tests for cutting fluids efficiency evaluation [1, 2, 3, 4]. Among the most considerable performance criteria in reaming belong reaming torque, reaming thurst, hole diameter oversize, hole geometry and surface roughness.

There are many independent influence parameters in reaming processes, such as machine, cutting tool, workpiece, cutting conditions, cutting fluid and parameters connected to the operator, his experience in performing cutting, choosing the correct measuring strategy and final data processing and evaluation. Therefore, a complete control over these influence quantities is necessary. One possibility of doing so is to calculate a dispersion of data or variability of data or calculating the uncertainty budget. This results in detailed description of all influence contributors and their impact on the overall uncertainty.

In reaming operation where a cutting tool with n edges is used, the surface is generated as a spiral having n leads. Depending on the lubrication conditions, reamed surfaces are typically furrowed or more random [1]. One of the main aims of this work was to investigate the ability of a cutting fluid to ensure a surface which is a replication of the reamer geometry and of the spiral path determined by the feed. Figure 1.1 shows a theoretical form of a surface generated by a reamer with six flutes used at a feed of six times the furrow width, w, per revolution. The profile produced by this tool is determined by the angle of entry of $45°$ and the relief angle, which is of the order of 1:100.

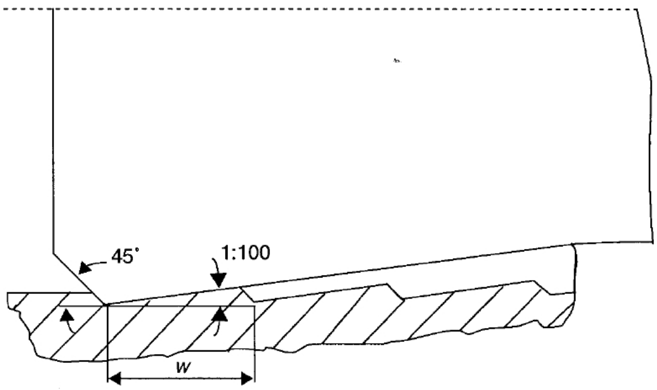


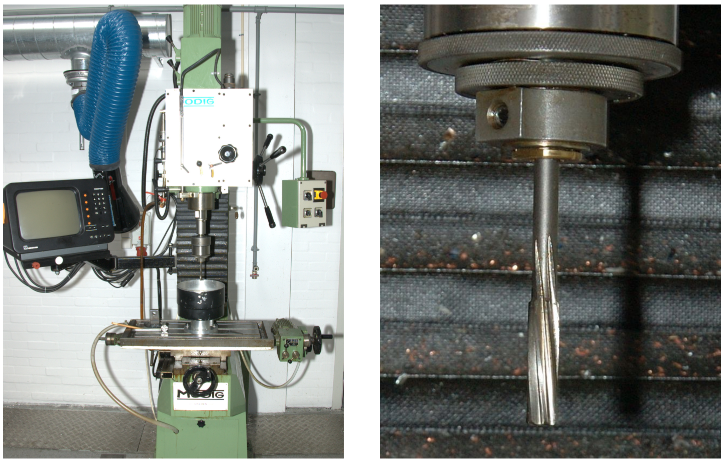
Figure 1.1: *A theoretical surface profile as a replication of a reamer geometry [1].*

Chapter 2

Cutting setup

2.1 Machine tool and tooling

All tests were carried out on a 3.7 kW radial drilling machine, Modig (see Figure 2.1(a)). Two high speed steel 6-flute machine reamers (see Figure 2.1(b)) with Ø10.2 mm were used for the tests. Reamer specifications are listed in Table 2.1. Reamers were clamped in a floating holder SK30 x MK3 Gewefa. Run-out less than 5 μm was measured.



(a) *3.7 kW radial drilling machine, Modig.*

(b) *6-flute HSS machine reamer.*

Figure 2.1: *Machine tool and cutting tool.*

2.2 Workpiece and cutting fluid

Specimens were austenitic steel AISI 316L, which is low-carbon grade, non-magnetic stainless steel, see workpiece material specification in Table 2.2.

Such material is hard to machine due to its ductility, high strain hardening and low thermal conductivity. Chips produced are long wiry chips, and the material can easily work harden if not machined with correct feeds. The test workpieces were rings with a

Table 2.1: Reamer specifications.

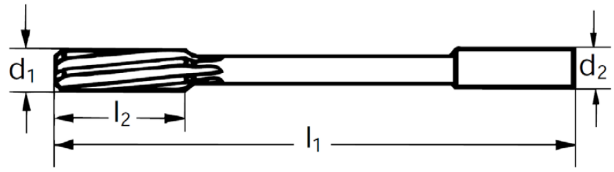
Chucking reamer DIN 212 - F1352 TITEX	
	
Material	HSS-E (COBALT)
Shank	cylindrical, DIN 212
No. of flutes	6
Helix angle, γ	7° left hand
Chamfer angle, κ	45°
Dimensions [mm]	
$l1$	133
$l2$	38
$d1$	10.2
$d2$	10.0h9
Tolerance	for H7 fit

Table 2.2: Workpiece material characteristics.

Workpiece material		AISI 316L Stainless steel	
Vickers Hardness		258.1 HV20	
Composition analysis			
Element	Mass [%]	Element	Mass [%]
C	0.016	Cr	17.31
Si	0.39	Mo	2.11
Mn	1.4	S	0.026
P	0.027	N	0.052
Ni	11.21		

pre-manufactured hole by drilling and grinding. Dimension, form and surface roughness specifications of workpieces can be seen in Figure 2.2. This was previously investigated in [5]. Workpieces were clamped in a holder so that the workpieces were fully immersed in the cutting fluid (see Figure 2.3). Tool holder and workpiece were aligned using a lever-type dial gauge.

Cutting fluids (CF) employed in this test are summarized in Table 2.3.

The concentration of the oil in water was measured by refractometer, see Figure 2.4.

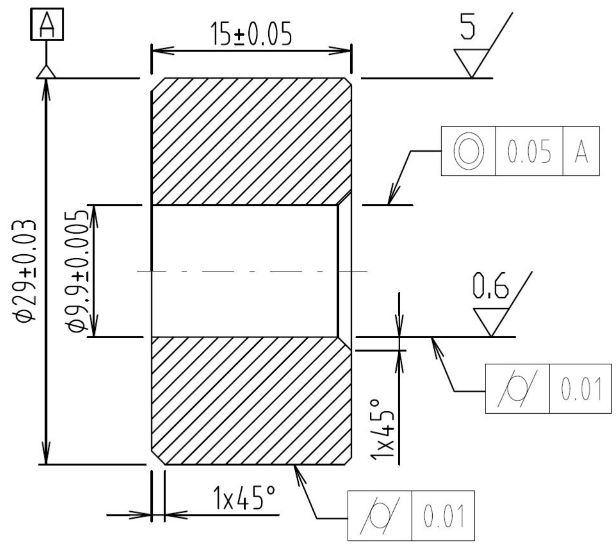


Figure 2.2: Workpiece dimensional characteristics.

Figure 2.3: Clamping of the workpiece and application of lubrication.

Table 2.3: An overview of cutting fluids.

Code	Description	Concentration (%)
W1	Amine-free Water-based cooling lubricant (Rhenus)	1
W2	Amine-free Water-based cooling lubricant (Rhenus)	10
M	Straight mineral oil	100
N	Additivated neat oil (TDN81) - chlorine, vegetables fats and sulphur	100

Figure 2.4: *Refractometer.*

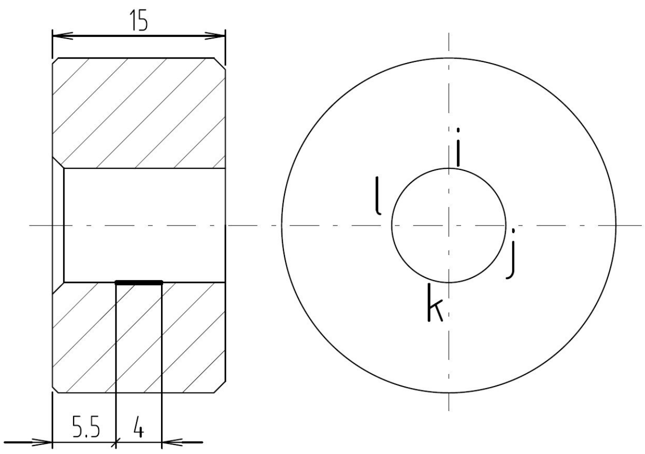
2.3 Measuring procedure

2.3.1 Surface roughness

The surface topography of the reamed holes was characterized in terms of conventional surface roughness parameter *Ra*, defined in ISO 4287 [6]. As discussed in [1], the *Ra* parameter is not appropriate to compare different machined surfaces; however, in the present investigation, where the focus is on process repeatability and tool replication, *Ra* was considered to be a convenient parameter. Measurements were carried out using a stylus roughness tester, Surtronic 4+ (Figure 2.5(a)), equipped with a skid pick-up and a 2 μm radius tip (Figure 2.5(b)) according to ISO 3274:1975 [7]. The resolution of the instrument is 0.01 mm. The workpieces were cleaned from chips before the measurement using an alcohol. Measuring profiles were recorded on the reamed specimens at 4 different positions equally distributed around the hole circumference, at a distance 5.5 mm from the top surface, see Figure 2.5(c). An evaluation length *ln* = 4 mm, low-pass λs = 0 μm and high-pass λc = 0.8 μm profile filtering, according to ISO 3274:1996 [8], were applied. According to this ISO standard, λs should be set to 2.5 μm, but since the tip radius of the stylus is 2 μm, λs was set to zero, since this has a minimum effect on the measurement result.

(a) *Surtronic 4+, Taylor Hobson.*

(b) *Skid pick-up and 2μm radius tip.*



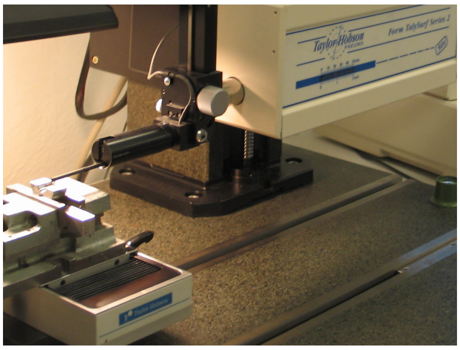
(c) *Surface roughness measurement strategy.*

Figure 2.5: *Surface roughness measurement setup.*

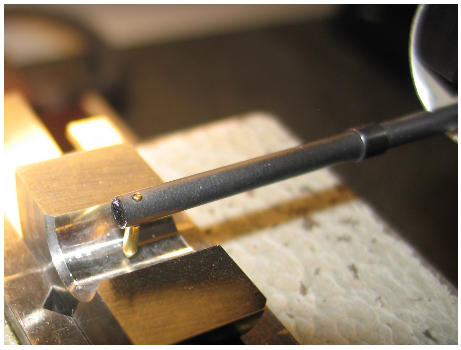
2.3.2 2D and 3D surface roughness reference measurements

Both 2D and 3D surface roughness measurements were performed using Form TalySurf Series 2 (Figure 2.6(a))and RTH TalySurf 5-120 measuring instruments, both from Taylor

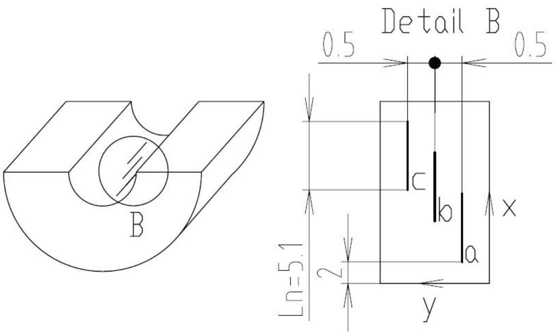
Hobson, equipped with a skidless pick-up and a 2 μm radius tip according to ISO 3274:1975 [7]. The measurement strategy for 2D and 3D measurements can be seen in Figure 2.6(c) and Figure 2.6(d). Profiles for 2D reference measurements were recorded starting approximately 2mm from the top surface of the workpiece, with evaluation length ln = 5.1 mm, low-pass $\lambda s = 0\ \mu$m and high-pass $\lambda c = 0.8\ \mu$m profile filtering, according to ISO 3274:1996 [8]. The second profile was taken starting approximately in the middle of the first one, 0.5 mm apart in y direction. The third profile was recorded in the same way as the second with respect to the first one. Profiles for 3D reference measurements were recorded on a measuring area 1 x 0.4 mm with spacing in between measuring profiles 1 μm ($\rightarrow$ 1000 samples) and 2 μm ($\rightarrow$ 200 samples) respectively, in the middle of the reamed specimens.



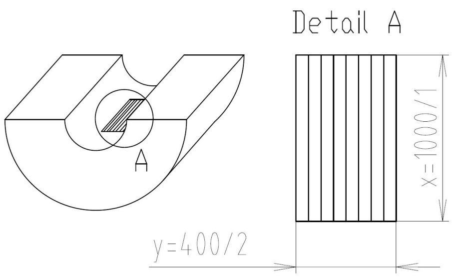
(a) *Form TalySurf Series 2, Taylor Hobson.*



(b) *Measurement position.*



(c) *2D reference measurement strategy.*



(d) *3D reference measurement strategy.*

Figure 2.6: *Surface roughness reference measurements.*

Specimens taken into consideration for reference measurements are listed in Table 2.4 and Table 2.5. It can be noticed that specimens measured by each of the reference instruments are from different operators (C and E) for cutting fluids W1, W2 and M and specimens for cutting fluid N are from the same operators (F and G). Here, for cutting fluid N, different specimens from the batch were used (P2 for measurements by Form TalySurf Series 2 and P3 for measurements by RTH TalySurf 5-1202).

Table 2.4: Specimens for surface roughness reference measurement using Form TalySurf Series 2.

WP indication	Cutting conditions				Code
	CF	Operator	f [mm/rev]	Reamer	
P2	W1	C	0.3	1	P/W1
P1	W2	C	0.3	1	P/W2
P1	M	C	0.3	1	P/M
P2	N	F	0.3	2	P0.3/N
P2	N	G	0.2	2	P0.2/N

P stands for low cutting speed (v_C = 4.5 m/min) and the number after P indicates workpiece number.

Table 2.5: Specimens for surface roughness reference measurement using RTH TalySurf 5-1202.

WP indication	Cutting conditions				Code
	CF	Operator	f [mm/rev]	Reamer	
P3	W1	E	0.3	1	P/W1
P1	W2	E	0.3	1	P/W2
P3	M	E	0.3	1	P/M
P3	N	F	0.3	2	P0.3/N
P3	N	G	0.2	2	P0.2/N

P stands for low cutting speed (v_C = 4.5 m/min) and the number after P indicates workpiece number.

2.3.3 Surface topography under microscope

Specimens reamed under different cutting conditions were examined for surface topography under the optical microscope. The microscope is InfiniteFocus, Alicona (see Figure 2.7), which is an optical 3D measurement device. The surface topography was measured with a 50x magnification. The surface of reamed holes was measured at three positions in the middle of the workpiece. The area measured was 290 x 218 μm.

Figure 2.7: *InfiniteFocus, Alicona, 3D optical microscope.*

Specimens taken into consideration for measurements on Alicona microscope are listed in Table 2.6.

Table 2.6: Specimens for surface roughness measurement under microscope.

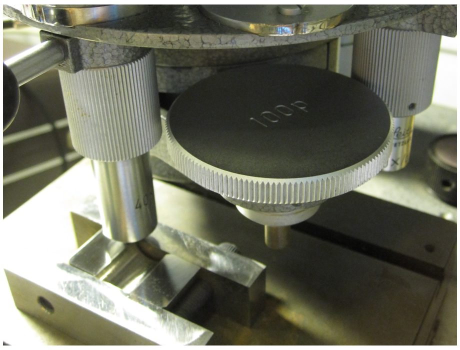
WP indication	Cutting conditions				Code
	CF	Operator	f [mm/rev]	Reamer	
P2	W1	C	0.3	1	P/W1
R2	W1	C	0.3	1	R/W1
P1	W2	C	0.3	1	P/W2
R3	W2	C	0.3	1	R/W2
P1	M	C	0.3	1	P/M
R1	M	C	0.3	1	R/M
P2	N	F	0.3	2	P0.3/N
P2	N	G	0.2	2	P0.2/N

P stands for low cutting speed (v_C = 4.5 m/min), R stands for high cutting speed (v_C = 10.2 m/min) and the number after indicates workpiece number.

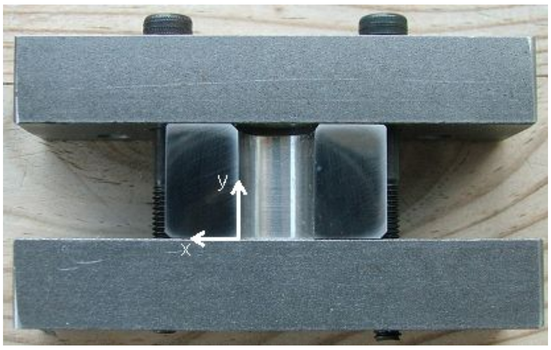
2.3.4 Microhardness

After roughness testing, the samples were milled in half and ground for microhardness tests. Because of the steep hardness gradients near the machined surface, the choice and preparation of the test surface into which the indentations are made is very important. Grinding papers with a grit between 180 and 1000 were used for approximately 1 min. Between changing the grinding papers, high pressure air was used to clean the specimens. The grinding was performed on a rotating plate with cold water. Microhardness testing with a Vickers indentor was carried out. The diagonal of the diamond pyramid was 20 μm. Calibration using reference materials with a given hardness was carried out before measurements on real workpieces. A load of 100 g (see Figure 2.8(a)) was applied for 18 sec to all specimens. The specimens were fixed and clamped in a fixture, see Figure 2.8(b). The microhardness value was determined as the average of five indentations taken at the same distance on the specimen's cross-sectional radius from edges, thus reducing the probability of systematic errors. The sequence of the indentations is shown in Table 2.7. The dimensions of the indentation were measured with a built-in function in the microscope (see Figure 2.8(c)), and the corresponding hardness value was found in a table. If the diagonals were unequal, an average value was calculated.

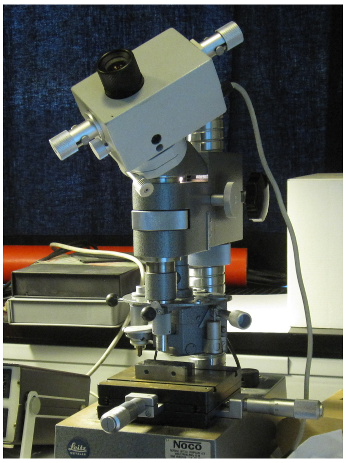
Specimens taken into consideration for the microhardness measurement are listed in Table 2.8.



(a) *Applied load.*



(b) *Specimen positioned in the fixture and coordinates for measuring strategy.*



(c) *Microscope.*

Figure 2.8: *Microhardness measurement setup.*

Table 2.7: Position of indentations for micro hardness measurement. See corresponding coordinate system in Figure 2.8(b).

Measurement in x [mm]	0.05	0.1	0.15	0.3	0.6	1.2	2.4
Measurement in y [mm]	2.5	5.0	7.5	10.0	12.5		

Table 2.8: Specimens for microhardness measurement.

WP indication	Cutting conditions				Code
	CF	Operator	f [mm/rev]	Reamer	
P3	W1	E	0.3	1	P/W1
R2	W1	E	0.3	1	R/W1
P1	W2	E	0.3	1	P/W2
R1	W2	E	0.3	1	R/W2
P1	M	E	0.3	1	P/M
R1	M	E	0.3	1	R/M
P2	N	F	0.3	2	P0.3/N
P2	N	G	0.2	2	P0.2/N

P stands for low cutting speed (v_C = 4.5 m/min), R stands for high cutting speed (v_C = 10.2 m/min) and the number after indicates workpiece number.

2.4 Test procedure

All the groups followed the same procedure which is described in 13 steps below:

1. Workpiece was clamped in the mounting device (holder);
2. Lubrication was applied so that the workpiece remained fully immersed;
3. The correct feed and rotational speed were set;
4. The pre-manufactured holes were reamed;
5. The reamer was examined for attached chips and these were respectively removed by compressed air;
6. This was repeated for two more workpieces;
7. Rotational speed was changed from 140 rpm to 320 rpm while keeping the same feed;
8. In this way, three workpieces were reamed;
9. The reservoir with the workpiece holder were cleaned and a new cutting fluid was applied;
10. The process was repeated for three cutting fluids;
11. Reamer was changed for a new one;
12. Five specimens were reamed for run-in;
13. The reaming process was repeated for additional cutting fluid, changing the feed from 0.3 mm/rev to 0.2 mm/rev and keeping the same rotational speed;

2.5 Test plan

Three specimens for combination of rotational speed/lubrication were reamed. This strategy was applied to five different operators (see Table 2.9 and Table 2.10) using reamer 1. This results in a total of 90 specimens (i.e. 5 operators, 3 cutting fluids, 2 rotational speeds and 3 specimens). Another serious of tests was performed using reamer 2 (new reamer) and a new CF. Ten specimens were reamed before the second series using reamer 2 was run in order to perform run-in. Then, six specimens were reamed according to the test plan, three with a feed 0.3 mm/rev and three with a feed 0.2 mm/rev, keeping the same rotational speed 140 rpm.

Table 2.9: Test plan.

CF	Operator						
	E*	A*	B*	C*	D*	F**	G***
W1	X	X	X	X	X		
W2	X	X	X	X	X		
M	X	X	X	X	X		
N						X	X

Note: The stars are further explained in Table 2.10.

Table 2.10: Cutting conditions.

	*	**	***	units
Cutting tool	Reamer 1	Reamer 2	Reamer 2	
Reamer diameter	10.2	10.2	10.2	mm/rev
Feed, f	0.3	0.3	0.2	mm/rev
Number of flutes	6	6	6	
Feed per tooth (chip load), CL	0.05	0.05	0.033	mm
Rotational speed, N_1	140	140	140	rpm
Cutting speed (low), P	4.5	4.5	4.5	m/min
Rotational speed, N_2	320			rpm
Cutting speed (high), R	10.2			m/min
Depth of cut, a_{p}	0.15	0.15	0.15	mm

It can be seen from Table 2.9 and Table 2.10 that the variables employed during the test were:

- operators (E, A, B, C, D, F, G);
- number of specimens for individual tests (WP1, WP2, WP3);
- cutting fluids CFs (see description of CFs in Table 2.3);
- cutting speeds (low: 4.5 m/min and high: 10.2 m/min);
- feeds (0.3 mm/rev and 0.2 mm/rev);
- reamers (Reamer 1 and Reamer 2).

Before the test, the actual rotational speeds 140 rpm and 320 rpm and feeds 0.3 mm/rev and 0.2 mm/rev were measured. The rotational speed of the spindle was measured by tachometer. The spindle displacement was measured over time on the NC console which is a part of a drilling press. The correct values of actual rotational speeds and feeds are shown in Table 2.11. It can be seen that the feed reduction (*FR*) for feed of 0.3 mm/rev was 7% (for both rotational speeds) whereas *FR* for feed of 0.2 mm/rev was 26.2%.

Table 2.11: Feed reduction.

	Parameter	Symbol	Value			Unit
Parameters set	Feed length	L	100	100	100	mm
	Rotational speed	N	140	320	140	rpm
	Feed	f	0.3	0.3	0.2	mm/rev
Measured values	Time	t	146	66	276	s
	Actual rotational speed	N'	147.3	326.0	147.3	rpm
Calculated values	Actual feed rate	fr'	41.1	90.9	21.7	mm/min
	Actual feed	f'	**0.279**	**0.279**	**0.148**	**mm/rev**
	Feed reduction	FR	**7.0**	**7.0**	**26.2**	**%**

Chapter 3

Expression of uncertainty for roughness measurement

An uncertainty for surface roughness measurements using a conventional stylus roughness tester was assessed taking into account calibration of this instrument and variability of the machined surface. The instrument was first calibrated using an optical flat, to determine the background noise and roughness standard ISO 5436 type C [9], to determine the repeatability of the measurement (see Calibration certificate in Appendix I). The uncertainty of the instrument was calculated U_{inst} = 0.016 μm. The expanded uncertainty of the instrument was calculated using the following formula:

$$U_{\mathrm{inst}} = k \times \sqrt{u_{\mathrm{n}}^2 + u_{\mathrm{r}}^2 + u_{\mathrm{b}}^2} \tag{3.1}$$

where

- k is a coverage factor corresponding to 95% confidence interval (k=2);
- u_{n} is uncertainty of the roughness calibration standard, U_{n} is from calibration certificate; $u_{\mathrm{n}} = \frac{U_{\mathrm{n}}}{2}$
- u_{r} is repeatability of the instrument, n is number of measurements in the same track with the standard deviation STD_{r}; $u_{\mathrm{r}} = \frac{STD_{\mathrm{r}}}{\sqrt{n}}$
- u_{b} is uncertainty caused by the background noise, *Rx0* is the measured background noise (average *Ra* measured on the optical flat); $u_{\mathrm{b}} = \frac{1}{2} \times \frac{Rx0}{\sqrt{3}}$

The individual uncertainty contributors and expanded combined uncertainty for measurements of the instrument were calculated and the results are shown in Table 3.1.

Table 3.1: Uncertainty budget for calibration of the stylus instrument. All values in μm.

Standard uncertainty components			Exp. comb. unc.
u_{n}	u_{r}	u_{b}	U_{inst}
0.008	0.001	0.005	0.016

The uncertainty budget (Table 3.2) of the reaming process was then calculated following GUM procedures [10], taking into account both the calibration of the stylus instrument and the variability of actual measurements on the specimen. The variability was assessed through repeated measurements at different locations on the workpiece, as explained in Section 2.3.1. The uncertainty was calculated as follows:

$$U_{\text{ream}} = k \times \sqrt{u_{\text{inst}}^2 + u_{\text{s}}^2} \tag{3.2}$$

where

- U_{ream} is expanded combined uncertainty for each combination of rotational speed and feed;
- *k* is a coverage factor corresponding to 95% confidence interval (*k*=2);
- u_{inst} is uncertainty of the instrument, $u_{\text{inst}} = U_{\text{inst}}/2$;
- u_s is uncertainty caused by variations in the roughness of the specimen in different locations, $u_{\text{S}} = s_{\text{S}}/\sqrt{n}$, where *n* is number of measurements (*n* = 60 for operators A, B, C, D, E and *n* = 12 for operators F, G) with standard deviation s_{S}.

Table 3.2: Uncertainty budget for the reaming process. All values in μm.

	Cutting condition							
	P/W1	P/W2	P/M	R/W1	R/W2	R/M	P0.3/N	P0.3/N
u_{inst}	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
u_{S}	0.016	0.012	0.012	0.039	0.028	0.023	0.007	0.008
U_{ream}	0.036	0.029	0.029	0.079	0.057	0.049	0.022	0.023

Chapter 4

Results and discussion

This chapter is dedicated to results achieved in this work. Results are discussed in different sections including investigation of Ra values and uncertainty calculation considering different uncertainty contributors, replication of the tool geometry, 2D and 3D reference measurements, investigation of surface roughness under the microscope, frequency analysis and microhardness measurements.

4.1 Ra values

Results shown in Figure 4.1 highlight clear idea about the influence of different cutting conditions on surface roughness parameter Ra. Individual columns in the graph represent average values coming from different operators, reaming process (including different workpieces) and measuring repeatability in the reamed hole. Error bars represent expanded uncertainty U_{ream}, expressed in Equation 3.2. It should also be noted, that the outliers and systematic errors were not eliminated. Low surface roughness values are due to specimens that were machined with low cutting speed (4.5 m/min), no matter what cutting fluid was used. Low uncertainties results from good reproducibility of the whole process, including both machining and measurements. Roughness of the specimens machined with high cutting speed (10.2 m/min), result in increased values and low process reproducibility which can be observed from bigger error bars when compared to low cutting speed. It can be seen that the uncertainty slightly decreases with increased concentration of the oil in solution (W1 compared to W2) or when straight mineral oil was used.

The influence of uncertainty contributors including repeatability around the hole circumference, repeatability of the process and reproducibility from different operators, is shown in Figure 4.2 and it is in a good agreement with Figure 4.1: individual uncertainty contributors are dependent on the selection of a combination of cutting speed/lubrication. It is shown in Figure 4.2 that the measuring repeatability in the reamed hole and process repeatability decreases with increased concentration of the oil (or when using a straight mineral oil) when high cutting speed was applied. However, it is generally difficult to describe which uncertainty contributor is more pronounced in the case of low cutting speed since this varies no matter which cutting fluid was used.

Individual uncertainty contributors in Figure 4.2 are calculated as following:

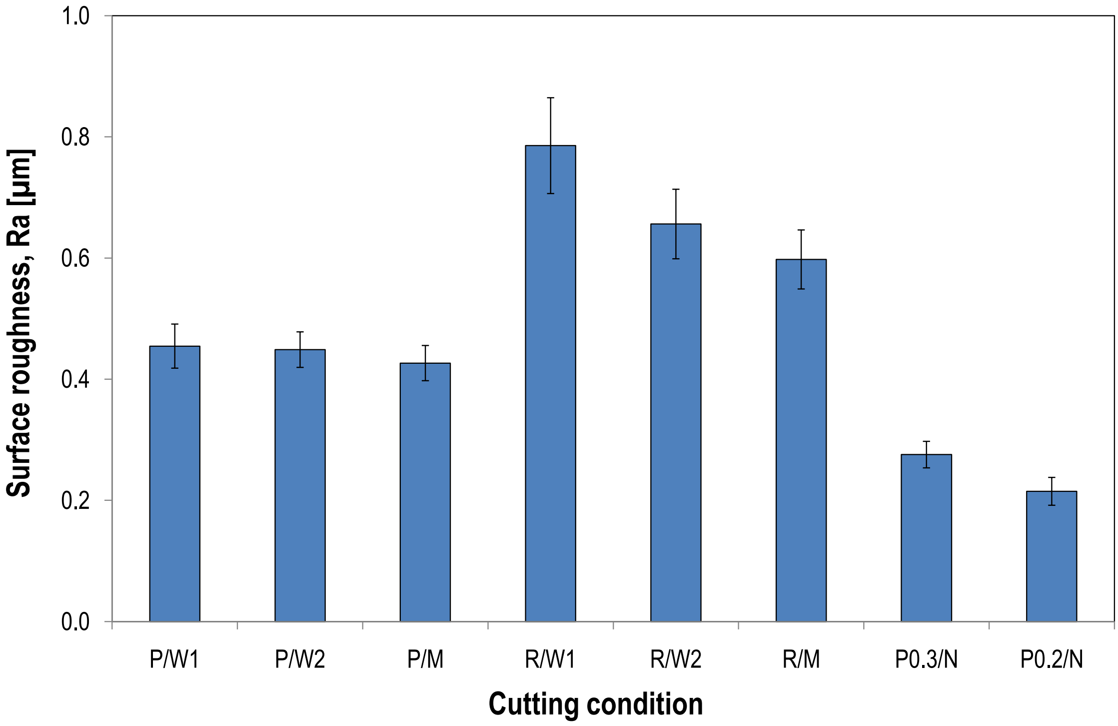


Figure 4.1: *Surface roughness measurement results. Error bars represent expanded measuring uncertainty at 95% confidence interval (k=2). The symbols refer to: Cutting speed (low P: 4.5 m/min and high R: 10.2 m/min), Feed (0.3 mm/rev and 0.2 mm/rev), Cutting fluid: W1, W2, M, N.*

- **instrument**: Calculated as $u_{\text{inst}} = U_{\text{inst}}/2$;
- **repeatability around hole circumference**: For four measured positions (i, j, k, l) a standard deviation is calculated. An average of three standard deviations, representing three workpieces, is calculated. From this, an average for five operators is considered;
- **repeatability of the process**: For four measured positions (i, j, k, l) an average is calculated. A standard deviation of three average values, representing three workpieces, is calculated. From this, an average for five operators is considered;
- **reproducibility of different operators**: An average of three workpieces measured at four positions (i, j, k, l) is calculated. From this, a standard deviation for five operators is considered.

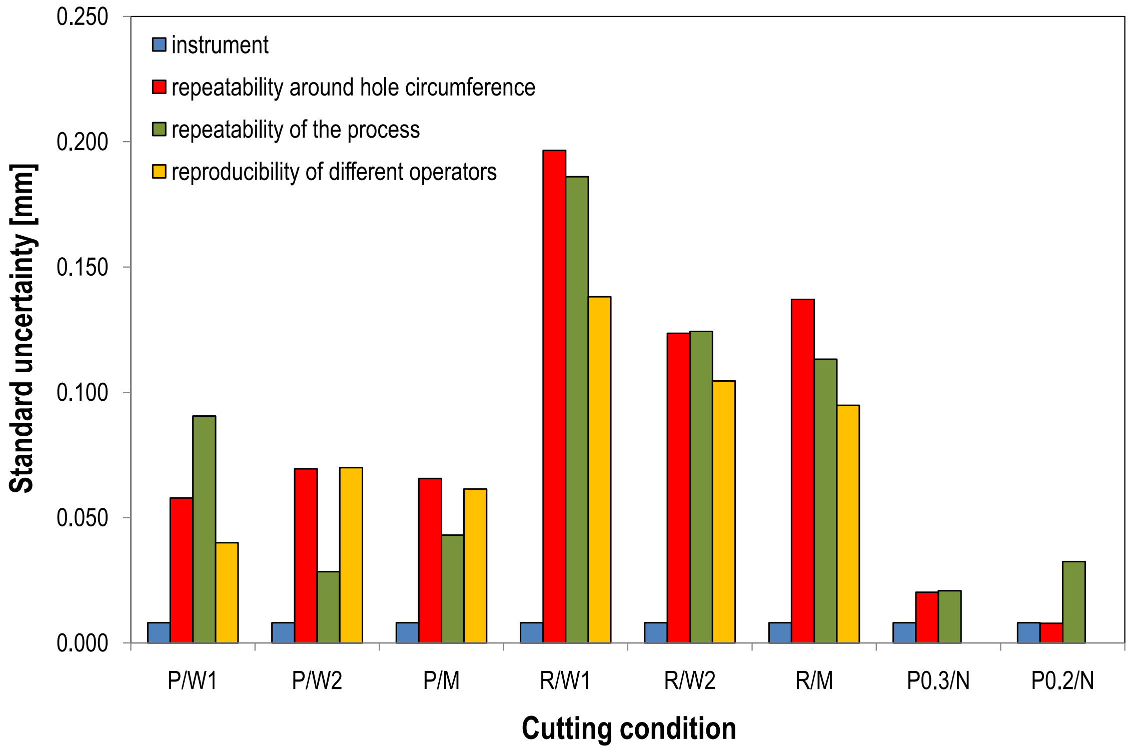


Figure 4.2: *Uncertainty caused by various contributors. The symbols refer to: Cutting speed (low P: 4.5 m/min and high R: 10.2 m/min), Feed (0.3 mm/rev and 0.2 mm/rev), Cutting fluid: W1, W2, M, N.*

It can be noticed from Figure 4.1 and Figure 4.2 that the new reamer in a combination with a chlorinated neat oil results in much lower surface roughness values and low uncertainties. This is because the contribution to uncertainty due to measurements around the hole circumference and repeatability of the process is lower, too. Moreover, the influence of the operator is not included in calculation.

In reaming tests generally, low Ra values can be combined with poor surface quality. However, it was observed in the present investigation that the low values of Ra surface roughness parameter correspond to good surface quality.

4.2 Replication

It is assumed that that the "long" wavelengths on the profiles correspond to feed marks coming from the cutting tool. As it can be seen in Figure 4.3, the number of peaks within an evaluation length ln = 4mm for a given feed f = 0.279 mm/rev is approximately 14. This is confirmed by a simple calculation, see below:

$$\frac{ln}{f} = \frac{4}{0.279} = 14.3\ peaks \tag{4.1}$$

Each peak on the profile therefore represents a feed mark caused by the reamer. The number of peaks for individual cutting conditions corresponds to the feed of the tool, however is more distinct for low cutting speed.

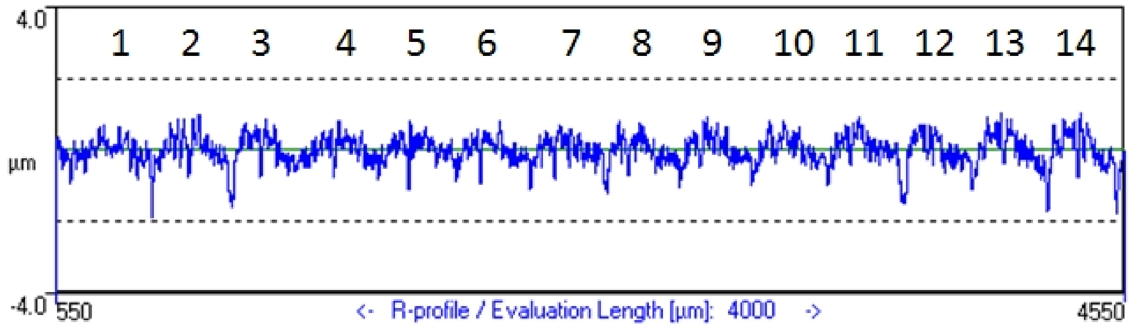


Figure 4.3: *Profile of a reamed surface. Each peak on the surface profile represents a feed that the tool moves per revolution.*

It can be seen from the profiles obtained from all the measurements (see Appendix A and Appendix B), that surfaces produced with a low cutting speed are generally reproducible when considering different operators, unlike the surfaces produced with high cutting speed. These result in uneven, random surface profiles and vary considerably for different operators. However, it can be observed that a higher concentration of the oil in water-based cutting fluid (or when using a straight mineral oil) results in surface profiles that are more reproducible at a higher cutting speed. Moreover, it can be seen that three cutting fluids (two water-based cutting fluids with different oil concentrations and a straight mineral oil) used in connection with a low cutting speed result in "identical" surface profiles.

Profiles presented in Figure 4.4, Figure 4.5 and Figure 4.6 confirm high reproducibility of surface roughness profiles for low cutting speed. It can be however observed that the surface roughness profiles in the case of W1 lubrication result in high reproducibility for individual specimens (measurements around the hole circumference) but vary for all three specimens reamed under the same conditions.

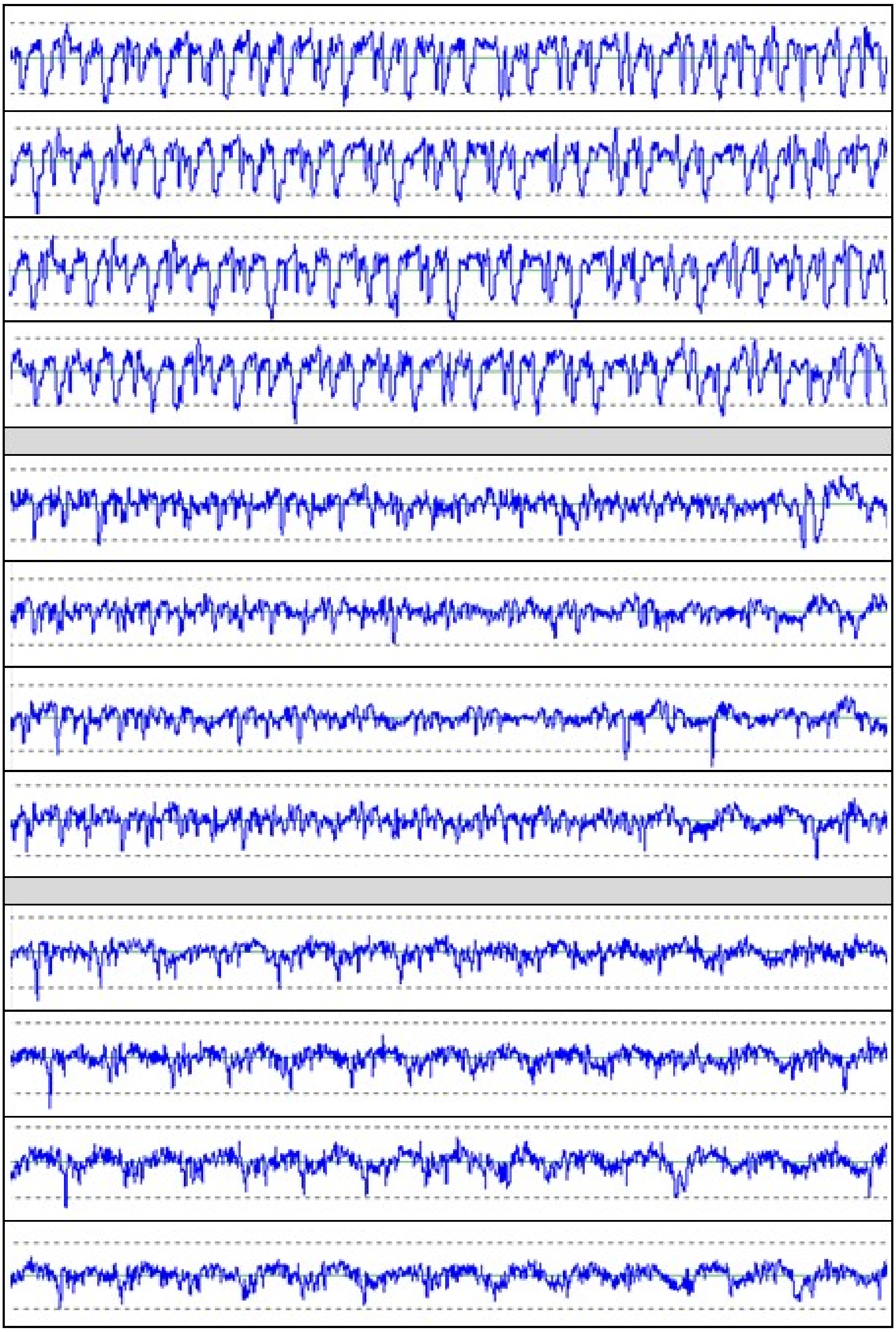


Figure 4.4: *Reproducibility of surface roughness profiles for operator E with the following cutting conditions: low cutting speed, water-miscible CF with 1% concentration (P/W1). The first four profiles represent WP1, the middle four profiles WP2 and the last four profiles WP3. The evaluation length is 4 mm and the height between the dotted lines corresponds to 4 μm.*

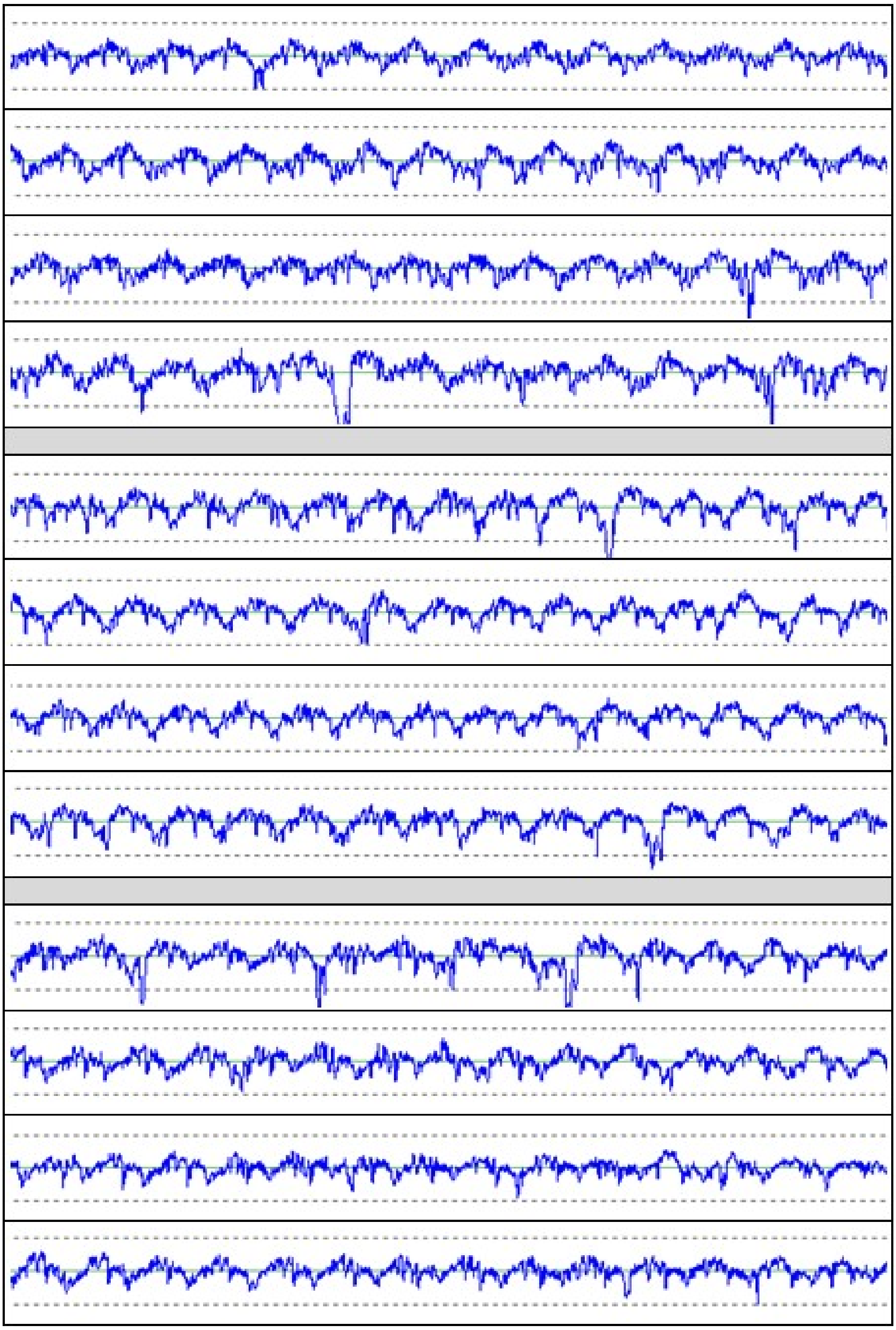


Figure 4.5: *Reproducibility of surface roughness profiles for operator E with the following cutting conditions: low cutting speed, water-miscible CF with 10% concentration (P/W2). The first four profiles represent WP1, the middle four profiles WP2 and the last four profiles WP3. The evaluation length is 4 mm and the height between the dotted lines corresponds to 4 μm.*

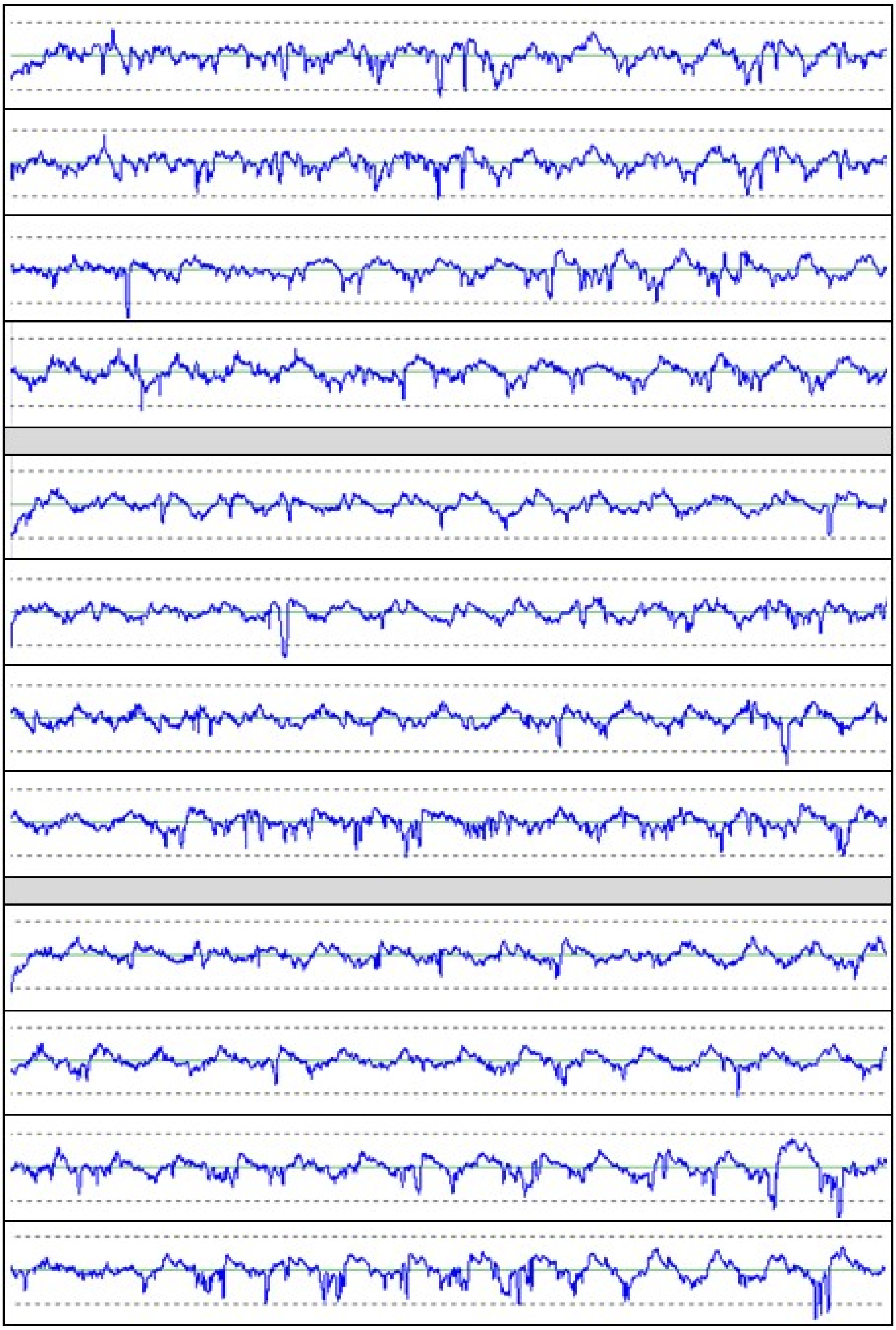
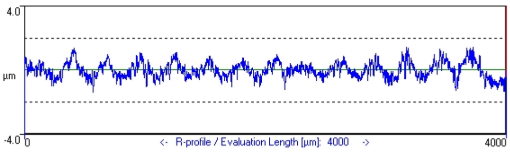
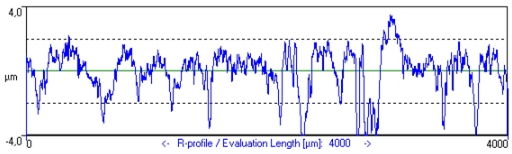


Figure 4.6: *Reproducibility of surface roughness profiles for operator E with the following cutting conditions: low cutting speed, straight mineral oil (P/M). The first four profiles represent WP1, the middle four profiles WP2 and the last four profiles WP3. The evaluation length is 4 mm and the height between the dotted lines corresponds to 4 μm.*

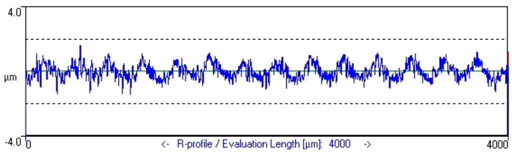
A significant difference was found when low cutting speed, feed 0.2 mm/rev and neat oil were used. In this case, profiles do not have so much characteristic appearance and feed marks cannot be observed. This can be seen for example in Figure 4.7, which shows characteristic profiles from different operators under specific cutting conditions. When cutting with high cutting speed, the feed marks are difficult to recognize either.



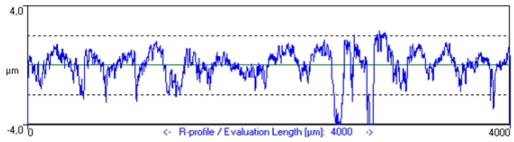
(a) *Operator C, P/W1.*



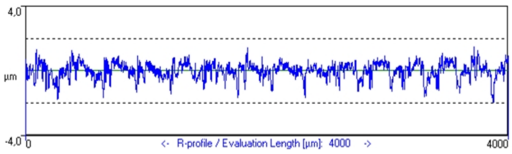
(b) *Operator A, R/W1.*



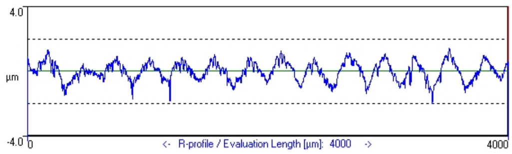
(c) *Operator C, P/W2.*



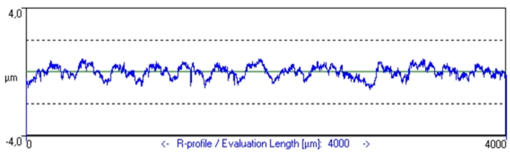
(d) *Operator B, R/W2.*



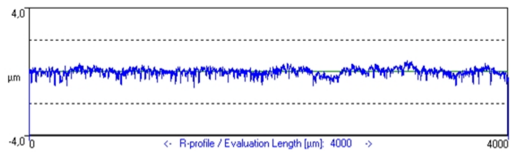
(e) *Operator A, P/M.*



(f) *Operator C, R/M.*



(g) *Operator F, P0.3/N.*



(h) *Operator G, P0.2/N.*

Figure 4.7: *Representative profiles for different cutting conditions.*

4.3 2D and 3D reference measurements

Profiles from 2D reference measurements can be found in Appendix C. Table 4.1 shows a comparison between *Ra* values obtained from a reference instrument and a conventional portable measuring instrument. A percentage deviation was calculated, and is expressed as follows:

$$DEV = \frac{conventional - reference}{reference} \times 100(\%) \tag{4.2}$$

Difference among values obtained from conventional and reference measurements was found. The difference is however random for both comparison measurements. First, the reason why measurements performed on a conventional and reference instruments are different may be due to different measuring strategies applied to both measuring instruments (see Figure 2.6(c) and Figure 2.5(c)). Secondly, such difference can be assigned to the use of skid pick-up in the case of conventional portable measuring instrument. The 'optimal' cutting condition leading to a good agreement between these measurements was found when higher feed and neat oil were used, resulting in a difference of approximantely 4%.

A qualitative comparison between conventional and reference measurements (two different reference instruments were used) is shown in Figure 4.8 and Figure 4.9. It can be seen that the surface topography has the same nature of the profile appearance and the difference is in the profile height. Profiles also revealed that using low feed and mineral straight oil leads to a clean cut.

Figure 4.10 shows profiles with a length corresponding to the actual feed of 0.279 mm/rev. The red lines then represent a furrow width, w, that is a width corresponding to individual flutes of the reamer and is calculated as follows:

$$w = \frac{feed}{number\ of\ flutes} = \frac{0.279}{6} = 46.5\mu m \tag{4.3}$$

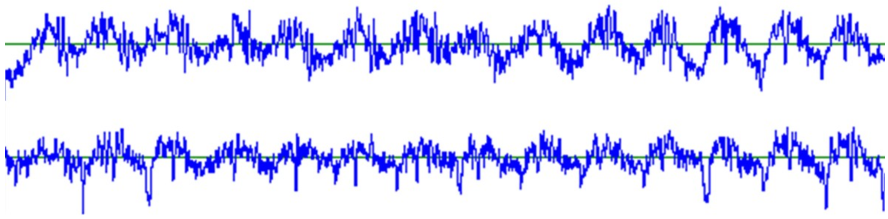
Replication of a geometry of the tool cannot be however recognized. More distinct replication of tool geometry can be observed on profiles from 3D measurement shown in Figure 4.11, which is a top view of 3D surface topography taken in SPIP software. Here, six furrow widths within the feed can be recognized, i.e. 46.5 μm for feed of 0.279 mm/rev and 24.6 μm for feed of 0.148 mm/rev from Table 2.11, respectively. 3D profiles along with a bearing ratio curve can be found in Appendix D. Marks after a rapid reverse motion of the spindle to the initial position can be noticed. Based on the surface profile from Figure 1.1, a theoretical depth of marks is approximately 46.5 μm/100 = 0.465 μm. Having this information in mind and looking at Figure 4.10 it can be concluded, that a build-up edge was present.

Table 4.1: Comparison between *Ra* values measured by reference instrument (ref1), Form TalySurf Series 2, and conventional portable measuring instrument (conv), Surtronic 4+. Symbols 1/i ... correspond to a measuring strategy (see Figure 2.6(c) and Figure 2.5(c))

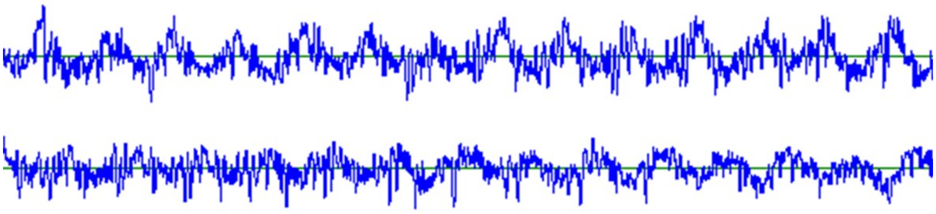
CF	Meas.type	1/i	2/j	3/k	l	*avg*	*s*	*DEV* [%]
W1	ref1	0.312	0.249	0.291		0.284	0.032	64
	conv	0.459	0.522	0.464	0.414	0.465	0.044	
W2	ref1	0.328	0.304	0.307		0.313	0.013	44
	conv	0.38	0.566	0.43	0.426	0.451	0.080	
M	ref1	0.285	0.244	0.256		0.262	0.021	46
	conv	0.454	0.399	0.337	0.341	0.383	0.055	
N	ref1	0.349	0.29	0.279		0.306	0.038	-5
	conv	0.258	0.299	0.287	0.323	0.292	0.027	
N	ref1	0.151	0.183	0.159		0.164	0.017	8
	conv	0.172	0.181	0.184	0.174	0.178	0.006	

Table 4.2: Comparison between *Ra* values measured by reference instrument (ref2), RTH TalySurf 5-120, and conventional portable measuring instrument (conv), Surtronic 4+. Symbols 1/i ... correspond to a measuring strategy (see Figure 2.6(c) and Figure 2.5(c)).

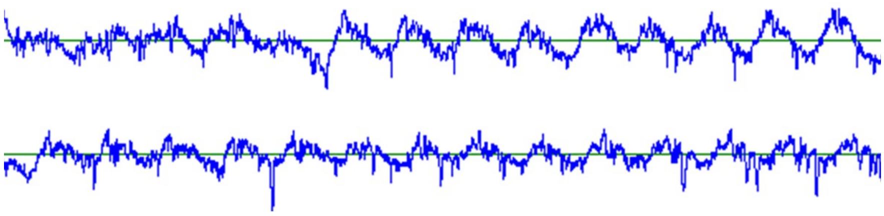
CF	Meas.type	1	2	3	4	*avg*	*s*	*DEV* [%]
W1	ref2	0.306	0.372	0.323		0.334	0.034	10
	conv	0.337	0.351	0.395	0.388	0.368	0.028	
W2	ref2	0.312	0.291	0.304		0.302	0.011	43
	conv	0.372	0.434	0.412	0.511	0.432	0.058	
M	ref2	0.253	0.322	0.389		0.321	0.068	19
	conv	0.328	0.345	0.424	0.438	0.384	0.055	
N	ref2	0.273	0.316	0.292		0.294	0.022	-4
	conv	0.283	0.291	0.26	0.296	0.283	0.016	
N	ref2	0.19	0.139	0.165		0.165	0.026	44
	conv	0.245	0.225	0.239	0.238	0.237	0.008	



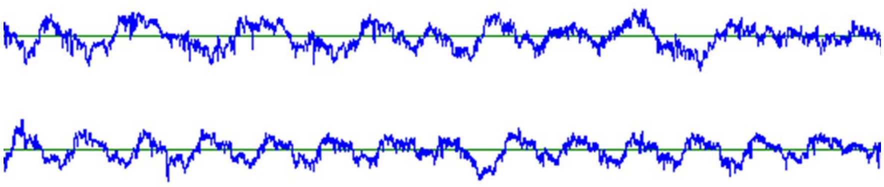
(a) *P/W1.*



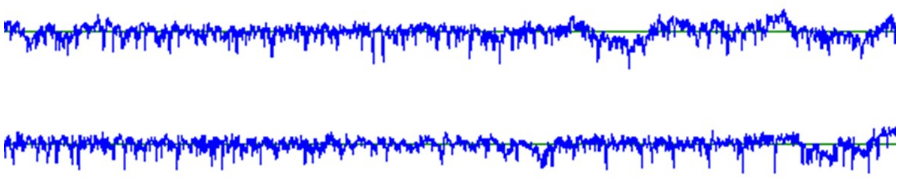
(b) *P/W2.*



(c) *P/M.*

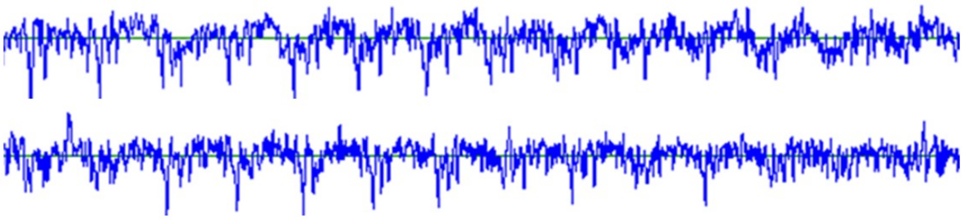


(d) *P0.3/N.*

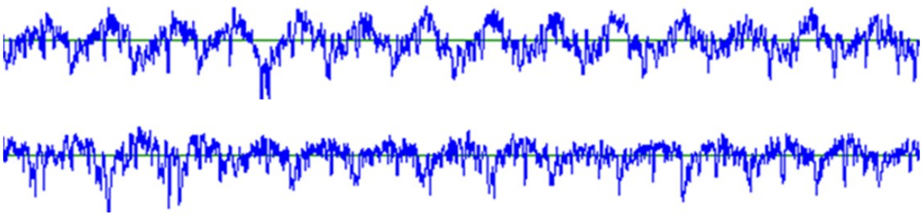


(e) *P0.2/N.*

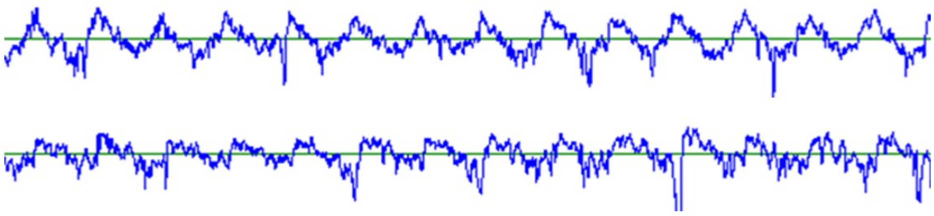
Figure 4.8: *Qualitative comparison of surface roughness profiles measured using conventional (Surtronic 4+) (top) and reference (Form TalySurf Series 2) (bottom) measuring instruments. The evaluation length is 4 mm and the height between the dotted lines corresponds to 4 μm.*



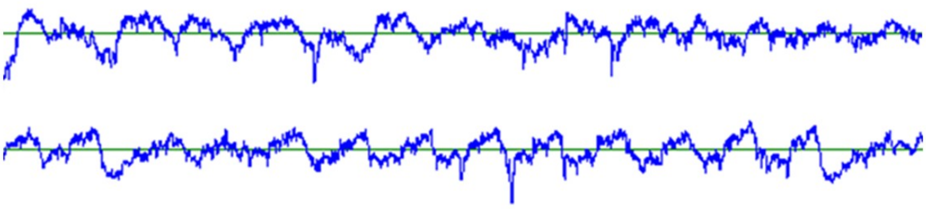
(a) *P/W1.*



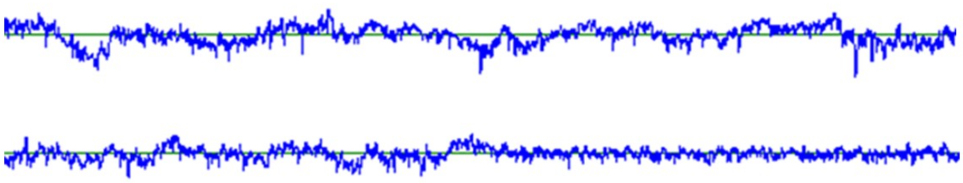
(b) *P/W2.*



(c) *P/M.*

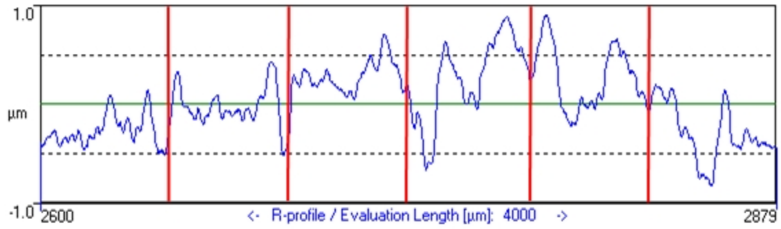


(d) *P0.3/N.*

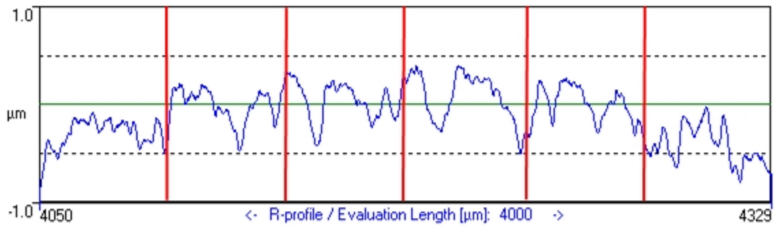


(e) *P0.2/N.*

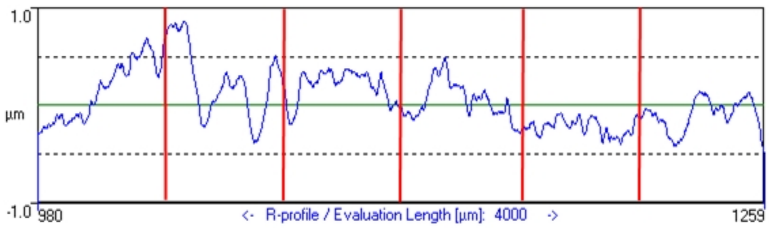
Figure 4.9: *Qualitative comparison of surface roughness profiles measured using conventional (Surtronic 4+) (top) and reference (RTH TalySurf 5-120) (bottom) measuring instruments. The evaluation length is 4 mm and the height between the dotted lines corresponds to 4 μm.*



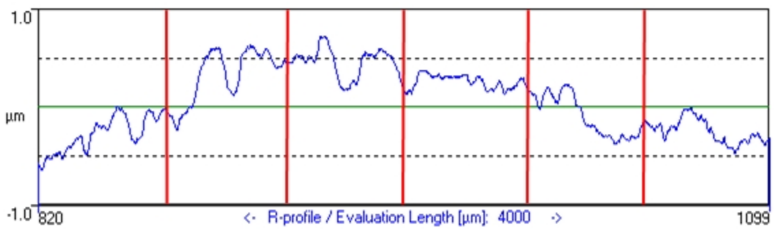
(a) *Furrow width, operator C, P/W1.*



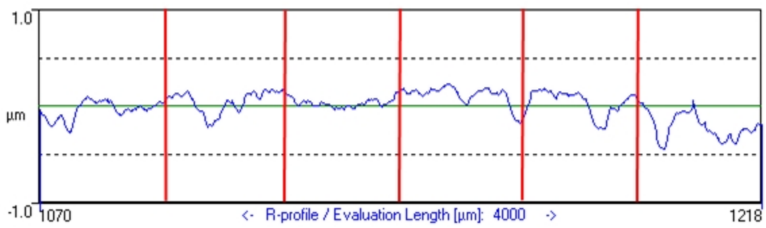
(b) *Furrow width, operator C, P/W2.*



(c) *Furrow width, operator C, P/M.*

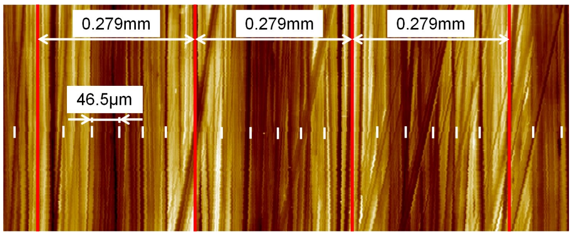


(d) *Furrow width, operator F, P0.3/N.*

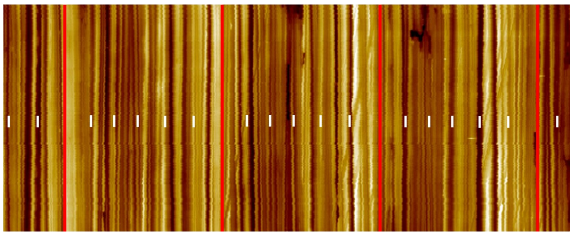


(e) *Furrow width, operator G, P0.2/N.*

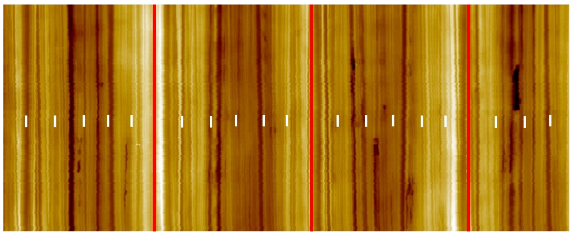
Figure 4.10: *Feed mark and furrow widths for different cutting conditions measured on a reference instrument (2D). Distance between the red lines corresponds to a furrow width.*



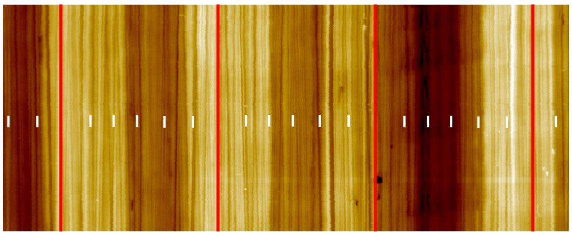
(a) *Furrow width, operator C, P/W1.*



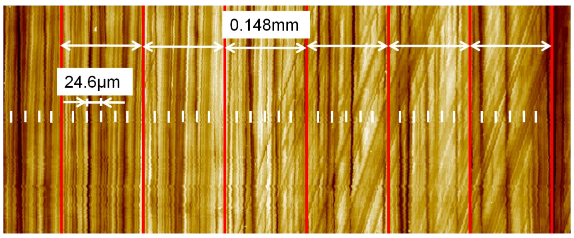
(b) *Furrow width, operator C, P/W2.*



(c) *Furrow width, operator C, P/M.*



(d) *Furrow width, operator F, P0.3/N.*

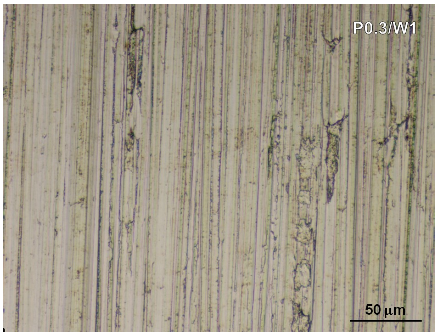


(e) *Furrow width, operator G, P0.2/N.*

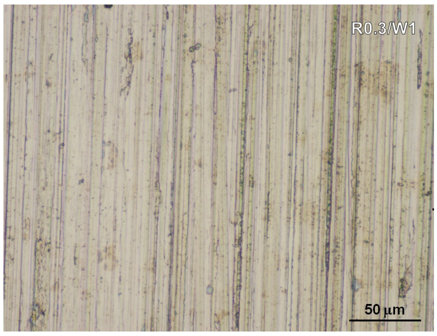
Figure 4.11: *Feed mark and furrow widths for different cutting conditions measured on a reference instrument (3D). The measuring area is 1 x 0.4 mm with spacing 1 μm (1000 samples) and 2 μm (200 samples). Distance between the red lines corresponds to a furrow width.*

4.4 Surface topography under microscope

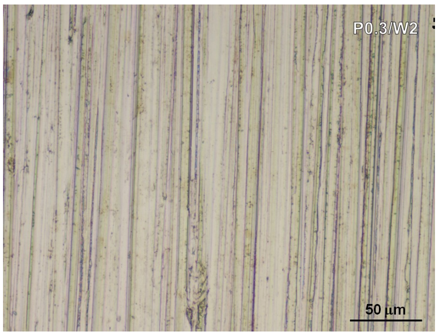
The results from the 3D optical measurements (see Figure 4.12) have shown that it is not easy to distinguish tool replication on reamed surfaces. Cutting condition enabling visual evidence of the tool replication, and so appearance of furrow width, was when low cutting speed was used in combination with mineral straight oil. 3D profiles along with bearing ratio curves can be found in Appendix F.



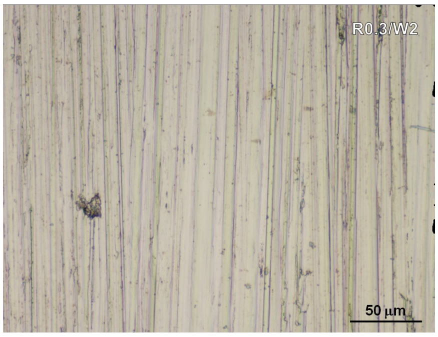
(a) *Operator C, P/W1.*



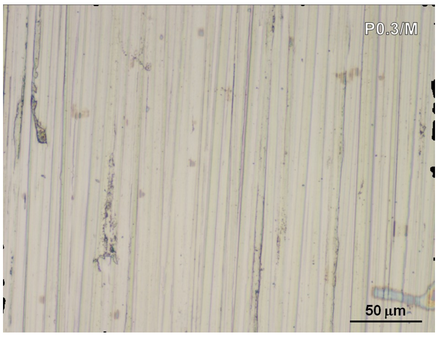
(b) *Operator A, R/W1.*



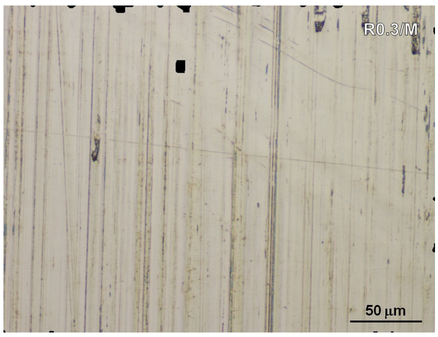
(c) *Operator C, P/W2.*



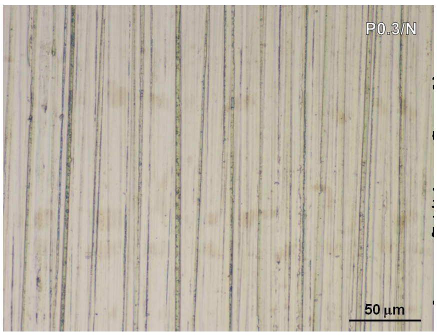
(d) *Operator B, R/W2.*



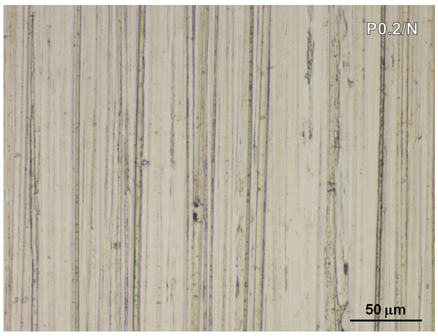
(e) *Operator A, P/M.*



(f) *Operator C, R/M.*



(g) *Operator F, P0.3/N.*

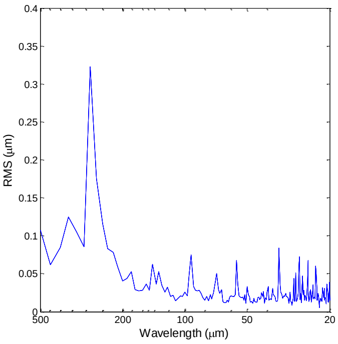


(h) *Operator G, P0.2/N.*

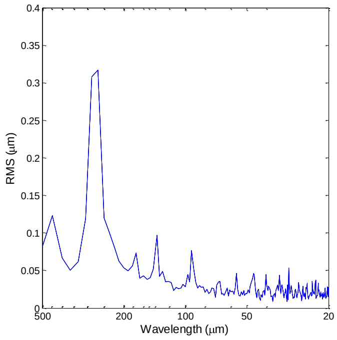
Figure 4.12: *Surface topography measured on a 3D optical microscope.*

4.5 Frequency analysis

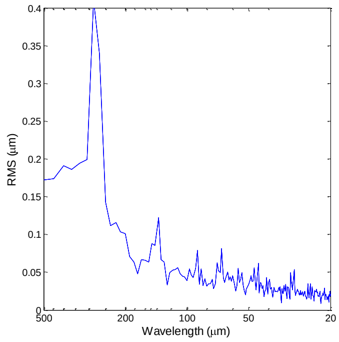
A spectral analysis of the profiles was performed in Matlab software. Graphs are plotted in linear and logarithmic scales. Each graph represents the average of four profiles which are taken around the hole circumference. Several remarks concerning the reproducibility of surface roughness can be stated. Surface profiles are generally reproducible at low speed for all lubrications, and are less reproducible at high speed. The latter concerns only lubrication W1. The surface analysis confirmed the previous conclusions from 2D surface roughness measurements. All the graphs are plotted in Appendix G.



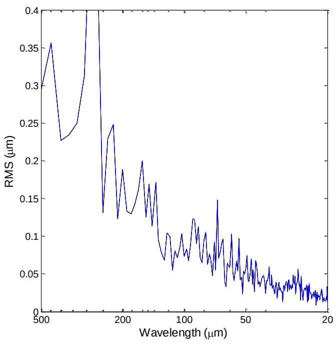
(a) *Operator C, P/W1.*



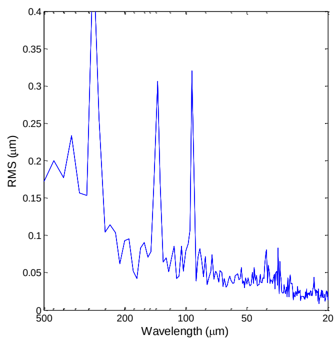
(b) *Operator C, P/W2.*



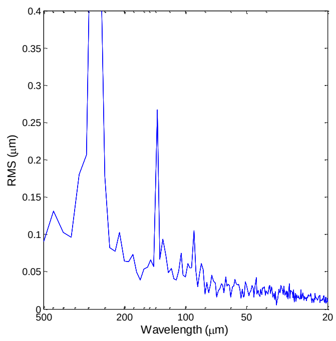
(c) *Operator C, P/M.*



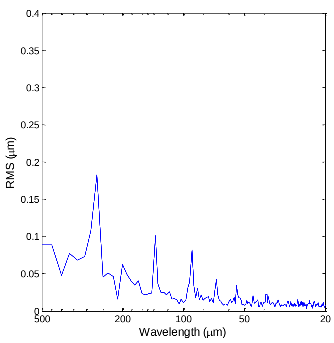
(d) *Operator A, R/W1.*



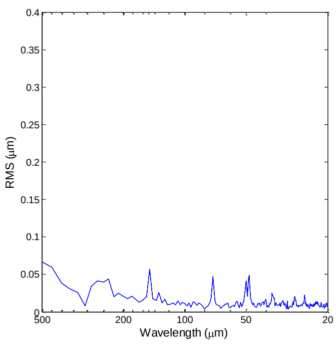
(e) *Operator A, R/W2.*



(f) *Operator A, R/M.*



(g) *Operator F, P0.3/N.*



(h) *Operator G, P0.2/N.*

Figure 4.13: *Representative profiles of frequency analysis in linear scale for different cutting conditions. Individual graphs are produced as an average of four single surface roughness profiles within one specimen.*

4.6 Microhardness

Based on the graph in Figure 4.14, the properties of the base material can be measured at a depth of approximately 200 μm where no strain hardening takes place. This is in a good agreement with that what was investigated in [1]. The microhardness value measured on the base material is $164<HV<174$ at a 95% confidence interval. It is shown that the microhardness is smaller when mineral oil and neat oil were used. This confirms good lubrication properties of these cutting fluids in reaming process. Microhardness measured close to the hole edge results in increased values by 65% from those measured on a base material. The standard deviation increases with a distance closer to the cut edge since the indentation at this location increases the systematic error. It is expected that the microhardness increases considerably even closer to the cutting edge, as is it shown in [1], at distances 30 μm and 15 μm respectively, where the microhardness can increase up to a 100% with respect to the base material microhardness.

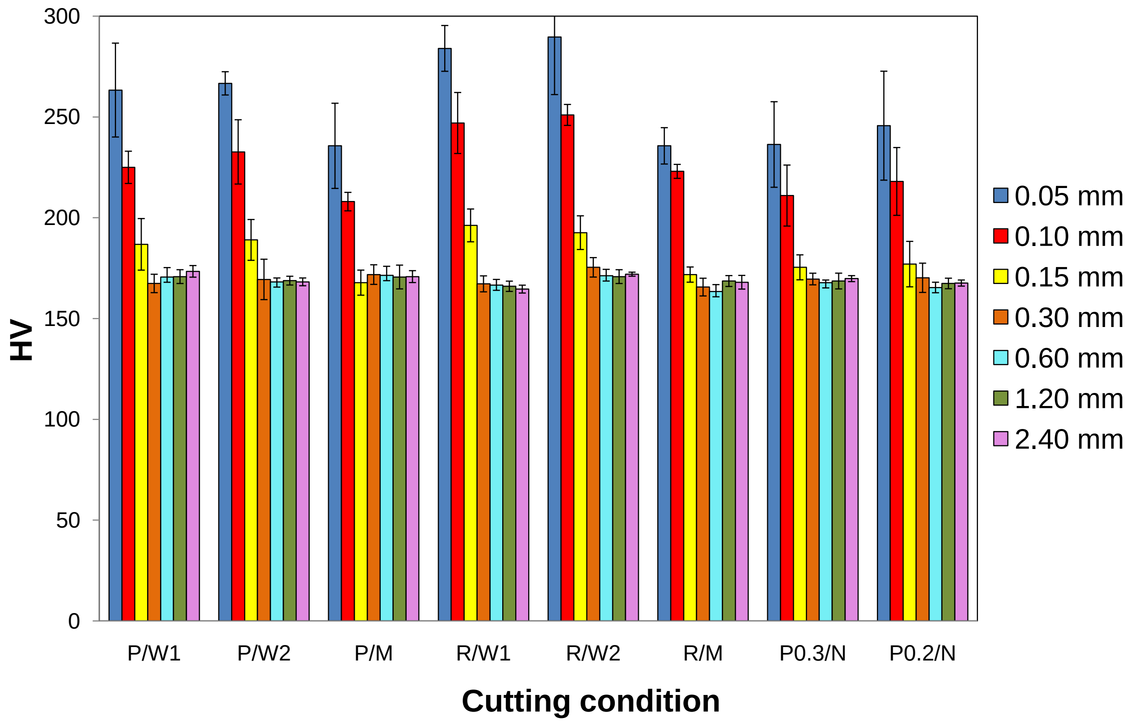


Figure 4.14: *Results of microhardness measurement. Error bars represent five repeated measurements at the same distance on the specimen's cross-sectional radius from edges.*

Chapter 5

Conclusion

An investigation on the reproducibility of surface roughness in reaming has been performed to document the applicability of this approach for testing cutting fluids. Reproducibility included three main factors: measuring repeatability in the reamed hole, repeatability of the process and reproducibility of different operators. It was observed from the profiles that surfaces produced with a low cutting speed were generally reproducible, unlike the surfaces produced with high cutting speed. These contained uneven, random surface profiles and varied considerably for different operators. However, it could be observed that a higher concentration of the oil in water-based cutting fluid (or when using a straight mineral oil) results in surface profiles that are more reproducible at higher cutting speed. Reproducibility from different operators was not significant and was the same for different cutting fluids. From the surface profiles, an identification of individual feed marks from the tool was possible. This was however more distinct for low cutting speed rather than high cutting speed.

References

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[5] W. Belluco, Performance testing of cutting fluids, Ph.D. thesis, Technical University of Denmark (2000).

[6] ISO 4287:1997 - Geometrical product specifications (GPS) - Surface texture: Profile method—terms, definitions and surface texture parameters.

[7] ISO 3274:1975 - Geometrical product specifications (GPS) - Surface texture: Profile method—nominal characteristics of contact (stylus) instruments.

[8] ISO 3274:1996 - Geometrical product specifications (GPS) - Surface texture: Profile method—nominal characteristics of contact (stylus) instruments.

[9] ISO 5436-1:2000 - Geometrical product specifications (GPS) - Surface texture: Profile method; measurement standards – Part 1: Material measures.

[10] ISO/IEC Guide 98-3:2008 - Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995).

Appendix A

Surface roughness measurement - Tables

Appendix A contains tables from all surface roughness measurements.

The values in table are corrected with a correction factor CF = 0.992 for operators E, A, B, C and D and CF = 0.990 for operators F and G. The assessment of CF is based on the calibration of the instrument.

All units in the following tables are in μm.

Table A1: Surface roughness measurement results – P/W1.

1% oil concentration, P(low speed vc=4.5m/min), N=140rpm, f=0.3mm/rev, reamer HSS Ø10.2mm												
	Operator E (23/3-2010)						Operator B (12/4-2010)					
	Position						Position					
	i	j	k	l	avg	std	i	j	k	l	avg	std
WP1	0.827	0.827	0.849	0.793	0.824	0.023	0.442	0.347	0.265	0.616	0.418	0.151
WP2	0.421	0.374	0.359	0.369	0.381	0.027	0.527	0.477	0.231	0.366	0.400	0.131
WP3	0.337	0.351	0.395	0.388	0.368	0.028	0.484	0.493	0.505	0.489	0.493	0.009
avg	0.528	0.517	0.534	0.517	0.524		0.484	0.439	0.334	0.490	0.437	
std	0.262	0.269	0.273	0.239	0.260		0.043	0.080	0.149	0.125	0.049	

1% oil concentration, P(low speed vc=4.5m/min), N=140rpm, f=0.3mm/rev, reamer HSS Ø10.2mm												
	Operator C (19/4-2010)						Operator A (26/4-2010)					
	Position						Position					
	i	j	k	l	avg	std	i	j	k	l	avg	std
WP1	0.479	0.491	0.382	0.460	0.453	0.049	0.351	0.368	0.389	0.443	0.388	0.040
WP2	0.459	0.522	0.464	0.414	0.465	0.044	0.474	0.697	0.527	0.542	0.560	0.096
WP3	0.472	0.440	0.417	0.300	0.407	0.075	0.393	0.380	0.384	0.423	0.395	0.019
avg	0.470	0.484	0.421	0.391	0.442		0.406	0.482	0.433	0.469	0.448	
std	0.010	0.041	0.041	0.082	0.030		0.063	0.187	0.081	0.064	0.097	

1% oil concentration, P(low speed vc=4.5m/min), N=140rpm, f=0.3mm/rev, reamer HSS Ø10.2mm						
	Operator D (3/5-2010)					
	Position					
	i	j	k	l	avg	std
WP1	0.365	0.386	0.413	0.454	0.405	0.038
WP2	0.424	0.423	0.379	0.495	0.430	0.048
WP3	0.366	0.457	0.364	0.548	0.434	0.088
avg	0.385	0.422	0.385	0.499	0.423	
std	0.034	0.036	0.025	0.047	0.016	

Table A2: Surface roughness measurement results – R/W1.

1% oil concentration, R(high speed vc=10.2m/min), N=320rpm, f=0.3mm/rev, reamer HSS Ø10.2mm												
	Operator E (23/3-2010)						Operator B (12/4-2010)					
	Position						Position					
	i	j	k	l	avg	std	i	j	k	l	avg	std
WP1	0.834	0.619	0.639	0.636	0.682	0.102	0.402	0.389	0.474	0.887	0.538	0.236
WP2	0.668	0.623	0.945	0.966	0.801	0.180	0.436	0.499	0.411	0.434	0.445	0.038
WP3	0.686	0.740	0.650	0.680	0.689	0.037	0.930	0.993	0.493	0.518	0.734	0.265
avg	0.729	0.661	0.745	0.761	0.724		0.589	0.627	0.459	0.613	0.572	
std	0.091	0.069	0.174	0.179	0.066		0.296	0.322	0.043	0.241	0.147	

1% oil concentration, R(high speed vc=10.2m/min), N=320rpm, f=0.3mm/rev, reamer HSS Ø10.2mm												
	Operator C (19/4-2010)						Operator A (26/4-2010)					
	Position						Position					
	i	j	k	l	avg	std	i	j	k	l	avg	std
WP1	0.982	1.307	0.978	1.921	1.297	0.444	0.588	1.000	0.853	0.611	0.763	0.198
WP2	0.456	0.451	0.474	0.489	0.468	0.017	1.087	0.572	0.614	0.594	0.717	0.247
WP3	1.186	1.111	0.668	0.714	0.920	0.267	0.804	1.352	1.144	0.707	1.002	0.299
avg	0.875	0.956	0.707	1.041	0.895		0.826	0.975	0.870	0.637	0.827	
std	0.377	0.448	0.254	0.770	0.415		0.250	0.391	0.265	0.061	0.153	

1% oil concentration, R(high speed vc=10.2m/min), N=320rpm, f=0.3mm/rev, reamer HSS Ø10.2mm						
	Operator D (3/5-2010)					
	Position					
	i	j	k	l	avg	std
WP1	0.819	0.750	0.946	0.690	0.801	0.110
WP2	0.682	1.029	1.632	0.942	1.071	0.402
WP3	0.919	0.686	0.816	0.900	0.830	0.106
avg	0.807	0.822	1.131	0.844	0.901	
std	0.119	0.182	0.438	0.135	0.148	

Table A3: Surface roughness measurement results – P/W2.

10% oil concentration, P(low speed vc=4.5m/min), N=140rpm, f=0.3mm/rev, reamer HSS ø10.2mm												
	Operator E (23/3-2010)						Operator B (12/4-2010)					
	Position						Position					
	i	j	k	l	avg	std	i	j	k	l	avg	std
WP1	0.372	0.434	0.412	0.511	0.432	0.058	0.316	0.471	0.299	0.372	0.365	0.078
WP2	0.492	0.452	0.401	0.460	0.451	0.038	0.328	0.483	0.394	0.310	0.379	0.078
WP3	0.464	0.399	0.324	0.345	0.383	0.063	0.461	0.485	0.302	0.350	0.400	0.088
avg	0.443	0.428	0.379	0.439	0.422		0.368	0.480	0.332	0.344	0.381	
std	0.063	0.027	0.048	0.085	0.035		0.080	0.008	0.054	0.031	0.018	

10% oil concentration, P(low speed vc=4.5m/min), N=140rpm, f=0.3mm/rev, reamer HSS ø10.2mm												
	Operator C (19/4-2010)						Operator A (26/4-2010)					
	Position						Position					
	i	j	k	l	avg	std	i	j	k	l	avg	std
WP1	0.380	0.566	0.430	0.426	0.451	0.080	0.446	0.466	0.497	0.479	0.472	0.021
WP2	0.436	0.399	0.372	0.363	0.393	0.033	0.451	0.449	0.570	0.449	0.480	0.060
WP3	0.365	0.356	0.578	0.357	0.414	0.109	0.424	0.436	0.400	0.426	0.422	0.015
avg	0.394	0.440	0.460	0.382	0.419		0.440	0.450	0.489	0.451	0.458	
std	0.037	0.111	0.106	0.038	0.029		0.014	0.015	0.085	0.027	0.032	

10% oil concentration, P(low speed vc=4.5m/min), N=140rpm, f=0.3mm/rev, reamer HSS ø10.2mm						
	Operator D (3/5-2010)					
	Position					
	i	j	k	l	avg	std
WP1	0.580	0.680	0.638	0.449	0.587	0.101
WP2	0.491	0.520	0.650	0.630	0.573	0.079
WP3	0.730	0.533	0.452	0.415	0.533	0.141
avg	0.600	0.578	0.580	0.498	0.564	
std	0.121	0.089	0.111	0.116	0.028	

Table A4: Surface roughness measurement results – R/W2.

10% oil concentration, R(high speed vc=10.2m/min), N=320rpm, f=0.3mm/rev, reamer HSS Ø10.2mm												
	Operator E (23/3-2010)						Operator B (12/4-2010)					
	Position						Position					
	i	j	k	l	avg	std	i	j	k	l	avg	std
WP1	0.734	0.637	0.636	0.587	0.649	0.062	0.763	0.585	0.523	0.665	0.634	0.104
WP2	0.605	0.629	0.455	0.547	0.559	0.077	0.515	0.775	0.986	0.599	0.719	0.209
WP3	0.844	0.870	0.887	0.933	0.884	0.037	0.755	0.596	0.692	0.428	0.618	0.142
avg	0.728	0.712	0.659	0.689	0.697		0.678	0.652	0.734	0.564	0.657	
std	0.120	0.137	0.217	0.212	0.168		0.141	0.107	0.234	0.122	0.054	

10% oil concentration, R(high speed vc=10.2m/min), N=320rpm, f=0.3mm/rev, reamer HSS Ø10.2mm												
	Operator C (19/4-2010)						Operator A (26/4-2010)					
	Position						Position					
	i	j	k	l	avg	std	i	j	k	l	avg	std
WP1	0.564	0.472	0.676	0.537	0.562	0.085	0.619	0.734	0.596	0.747	0.674	0.078
WP2	0.485	0.413	0.448	0.443	0.447	0.030	0.932	0.493	0.935	1.094	0.864	0.258
WP3	0.475	0.373	0.429	0.400	0.419	0.044	0.661	0.717	0.690	0.574	0.661	0.062
avg	0.508	0.419	0.518	0.460	0.476		0.737	0.648	0.740	0.805	0.733	
std	0.049	0.050	0.137	0.070	0.076		0.170	0.135	0.175	0.265	0.114	

10% oil concentration, R(high speed vc=10.2m/min), N=320rpm, f=0.3mm/rev, reamer HSS Ø10.2mm						
	Operator D (3/5-2010)					
	Position					
	i	j	k	l	avg	std
WP1	0.604	0.510	0.685	0.707	0.627	0.089
WP2	0.504	1.125	1.647	0.558	0.959	0.538
WP3	0.533	0.562	0.558	0.622	0.569	0.038
avg	0.547	0.732	0.963	0.629	0.718	
std	0.051	0.341	0.595	0.075	0.210	

Table A5: Surface roughness measurement results – P/M.

Mineral oil, P(low speed vc=4.5m/min), N=140rpm, f=0.3mm/rev, reamer HSS Ø10.2mm												
	Operator E (23/3-2010)						Operator B (12/4-2010)					
	Position						Position					
	i	j	k	l	avg	std	i	j	k	l	avg	std
WP1	0.419	0.378	0.381	0.391	0.392	0.019	0.368	0.303	0.282	0.262	0.304	0.046
WP2	0.336	0.325	0.328	0.362	0.338	0.017	0.380	0.420	0.388	0.342	0.383	0.032
WP3	0.328	0.345	0.424	0.438	0.384	0.055	0.403	0.604	0.283	0.310	0.400	0.145
avg	0.361	0.349	0.378	0.397	0.371		0.384	0.442	0.318	0.305	0.362	
std	0.050	0.027	0.048	0.038	0.029		0.018	0.152	0.061	0.040	0.051	

Mineral oil, P(low speed vc=4.5m/min), N=140rpm, f=0.3mm/rev, reamer HSS Ø10.2mm												
	Operator C (19/4-2010)						Operator A (26/4-2010)					
	Position						Position					
	i	j	k	l	avg	std	i	j	k	l	avg	std
WP1	0.454	0.399	0.337	0.341	0.383	0.055	0.615	0.555	0.682	0.513	0.591	0.074
WP2	0.531	0.435	0.421	0.350	0.434	0.074	0.434	0.425	0.371	0.594	0.456	0.096
WP3	0.351	0.434	0.455	0.547	0.447	0.081	0.429	0.347	0.432	0.482	0.423	0.056
avg	0.445	0.423	0.404	0.413	0.421		0.493	0.442	0.495	0.530	0.490	
std	0.090	0.021	0.061	0.116	0.034		0.106	0.105	0.165	0.058	0.089	

Mineral oil, P(low speed vc=4.5m/min), N=140rpm, f=0.3mm/rev, reamer HSS Ø10.2mm						
	Operator D (3/5-2010)					
	Position					
	i	j	k	l	avg	std
WP1	0.533	0.490	0.368	0.582	0.493	0.092
WP2	0.482	0.595	0.436	0.473	0.497	0.069
WP3	0.558	0.515	0.428	0.401	0.476	0.073
avg	0.524	0.533	0.411	0.485	0.488	
std	0.039	0.055	0.037	0.091	0.011	

Table A6: Surface roughness measurement results - R/M.

Mineral oil, R(high speed vc=10.2m/min), N=320rpm, f=0.3mm/rev, reamer HSS Ø10.2mm												
	Operator E (23/3-2010)						Operator B (12/4-2010)					
	Position						Position					
	i	j	k	l	avg	std	i	j	k	l	avg	std
WP1	0.358	0.304	0.310	0.329	0.325	0.024	0.451	0.306	0.388	1.017	0.541	0.323
WP2	0.400	0.283	0.362	0.474	0.380	0.080	1.115	0.279	0.749	0.187	0.583	0.432
WP3	0.420	0.405	0.378	0.498	0.425	0.052	0.354	0.717	0.983	0.596	0.663	0.262
avg	0.393	0.331	0.350	0.434	0.377		0.640	0.434	0.707	0.600	0.595	
std	0.032	0.065	0.036	0.091	0.050		0.414	0.245	0.300	0.415	0.062	

Mineral oil, R(high speed vc=10.2m/min), N=320rpm, f=0.3mm/rev, reamer HSS Ø10.2mm												
	Operator C (19/4-2010)						Operator A (26/4-2010)					
	Position						Position					
	i	j	k	l	avg	std	i	j	k	l	avg	std
WP1	0.461	0.480	0.493	0.493	0.482	0.015	0.639	0.637	0.737	0.793	0.702	0.077
WP2	0.710	0.692	0.436	0.529	0.592	0.132	0.662	0.797	0.702	0.744	0.726	0.058
WP3	0.440	0.448	0.570	0.427	0.471	0.066	1.499	1.497	1.442	0.878	1.329	0.302
avg	0.537	0.540	0.500	0.483	0.515		0.933	0.977	0.960	0.805	0.919	
std	0.150	0.133	0.067	0.052	0.067		0.490	0.457	0.418	0.068	0.355	

Mineral oil, R(high speed vc=10.2m/min), N=320rpm, f=0.3mm/rev, reamer HSS Ø10.2mm						
	Operator D (3/5-2010)					
	Position					
	i	j	k	l	avg	std
WP1	0.468	0.453	0.512	0.464	0.474	0.026
WP2	0.309	0.358	0.645	0.363	0.419	0.153
WP3	0.368	0.415	0.496	0.397	0.419	0.055
avg	0.382	0.409	0.551	0.408	0.437	
std	0.080	0.048	0.082	0.051	0.032	

Table A7: Surface roughness measurement results - P0.3/N.

Neat oil, P(low speed vc=4.5m/min), N=140rpm, f=0.3mm/rev, reamer HSS Ø10.2mm (new)						
	Operator F (22/6-2010)					
	Position					
	i	j	k	l	avg	std
WP1	0.251	0.272	0.229	0.256	0.252	0.018
WP2	0.258	0.299	0.287	0.323	0.292	0.027
WP3	0.283	0.291	0.260	0.296	0.283	0.016
avg	0.264	0.287	0.259	0.292	0.275	
std	0.017	0.014	0.029	0.034	0.021	

Table A8: Surface roughness measurement results - P0.2/N.

Neat oil, P(low speed vc=4.5m/min), N=140rpm, f=0.2mm/rev, reamer HSS Ø10.2mm (new)						
	Operator G (22/6-2010)					
	Position					
	i	j	k	l	avg	std
WP1	0.233	0.243	0.222	0.225	0.231	0.009
WP2	0.172	0.181	0.184	0.174	0.178	0.006
WP3	0.245	0.225	0.239	0.238	0.237	0.008
avg	0.217	0.216	0.215	0.212	0.215	
std	0.039	0.032	0.028	0.034	0.032	

Appendix B

Surface roughness measurement - Profiles

Appendix B contains profiles from all the operators (i.e. E, A, B, C, D, F, G). The instrument was Surtronic 4+, Taylor Hobson.

Symbols in the tables (i, j, k, l) correspond to a position of the profile around the hole circumference.

P: Low speed, 4.5 m/min
R: High speed, 10.2 m/min

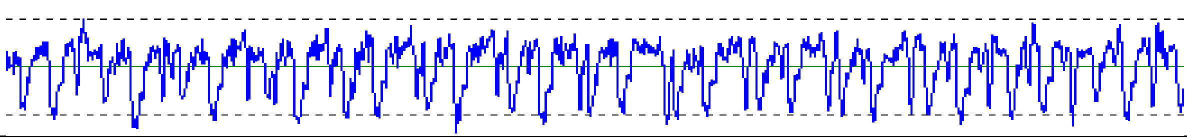
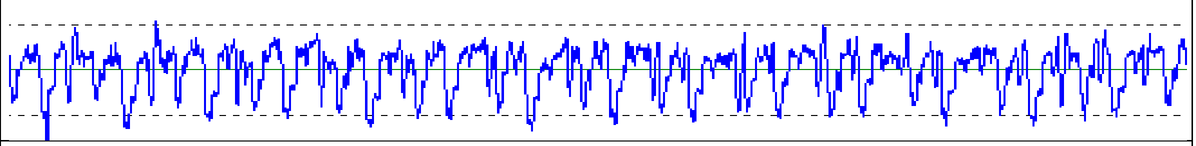
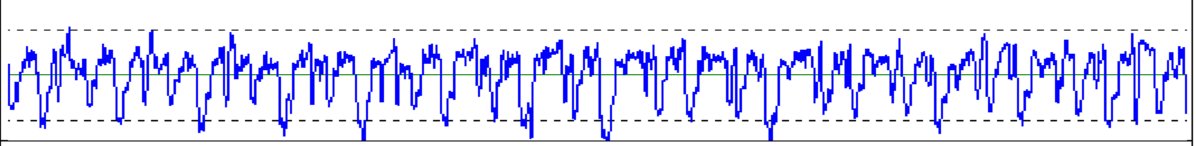
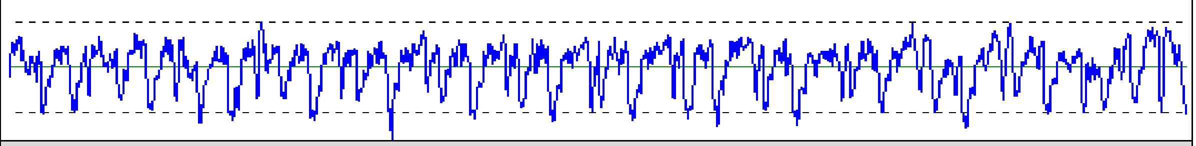
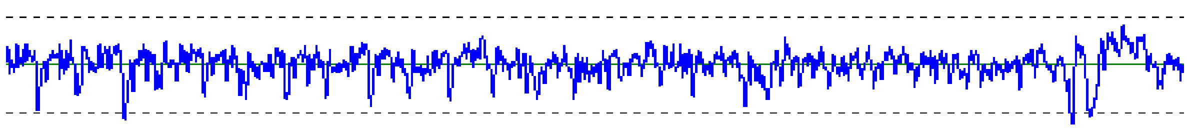
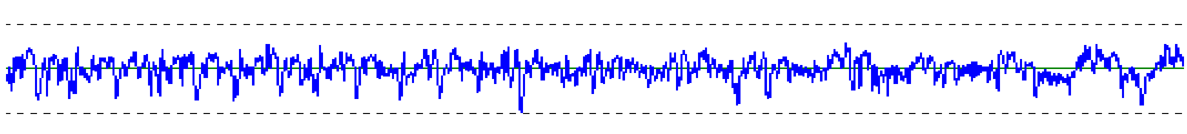
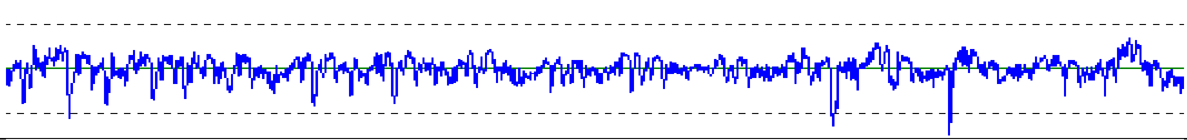
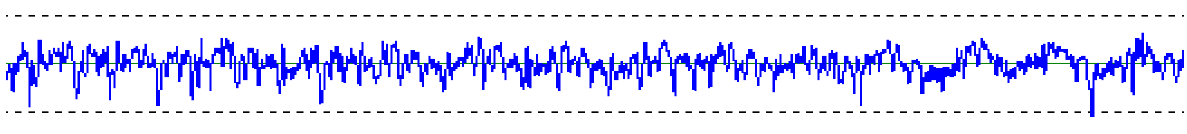
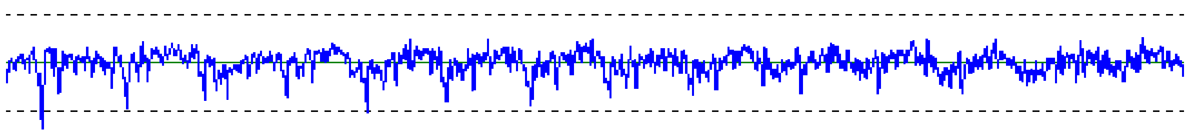
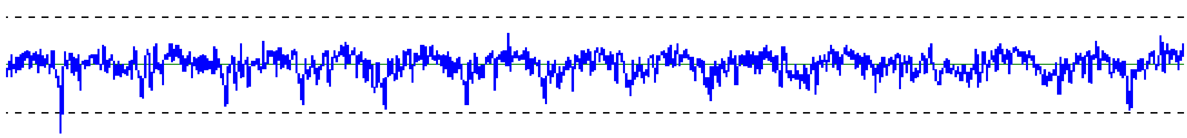
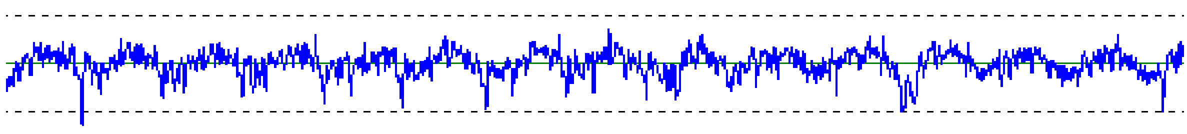
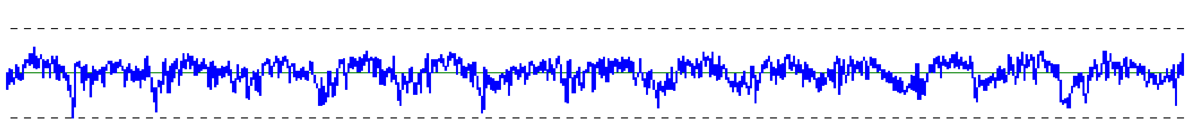
Feed, 0.3 mm/rev (operators A, B, C, D, E and F)
Feed, 0.2 mm/rev (operator G)

Evaluation length, 4mm
The height between the dotted lines is 4 μm.

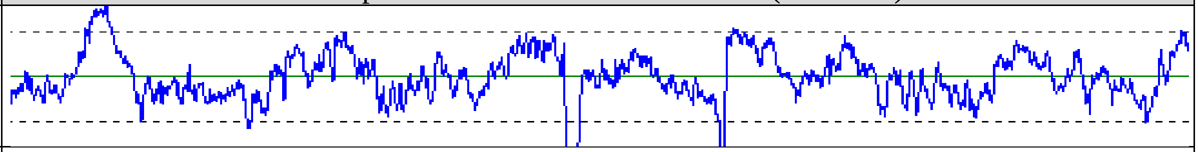
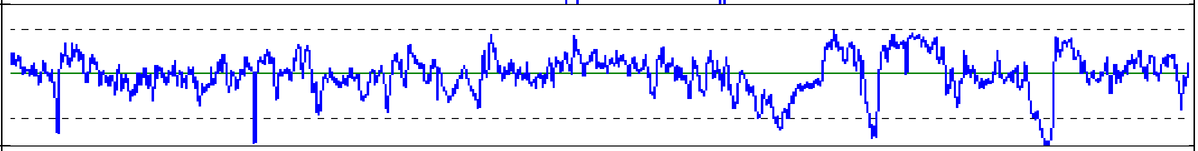
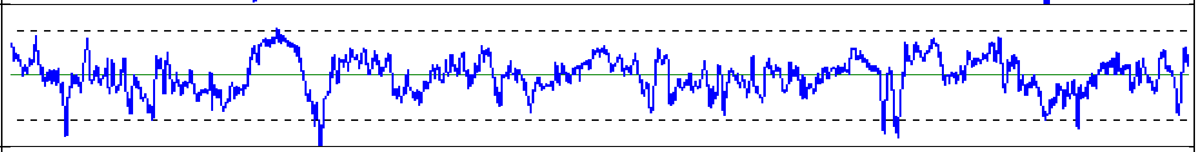
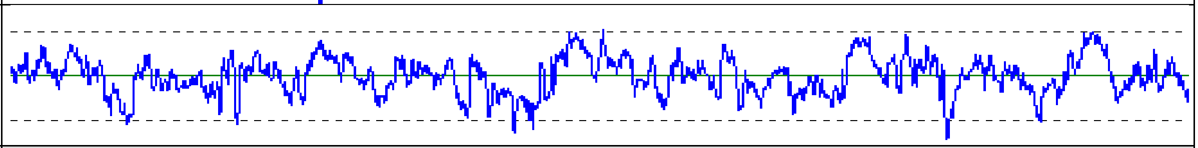
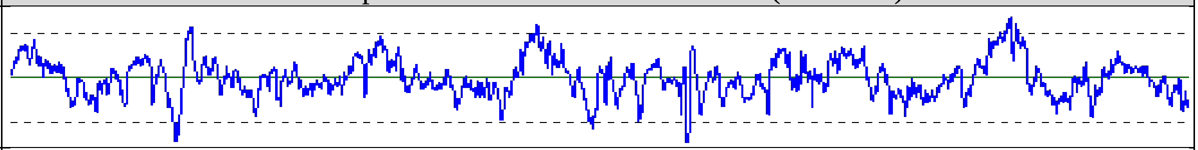
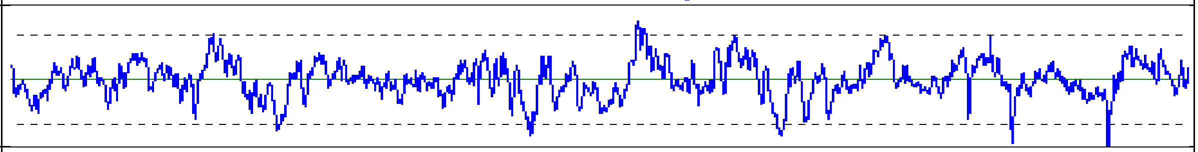
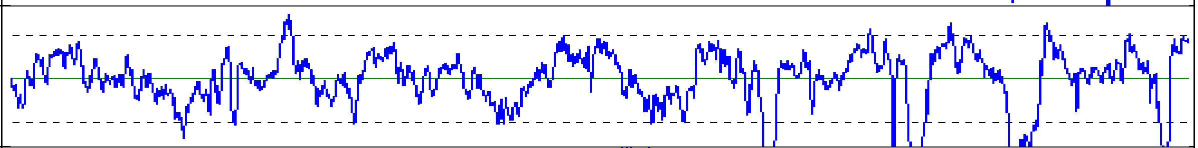
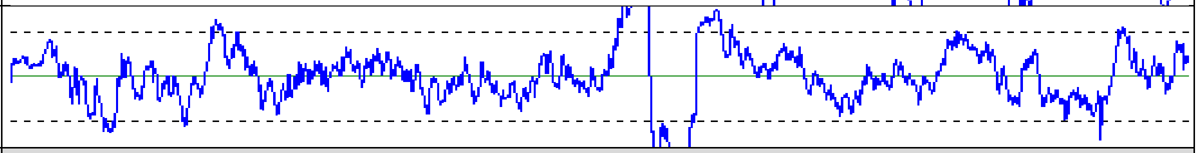
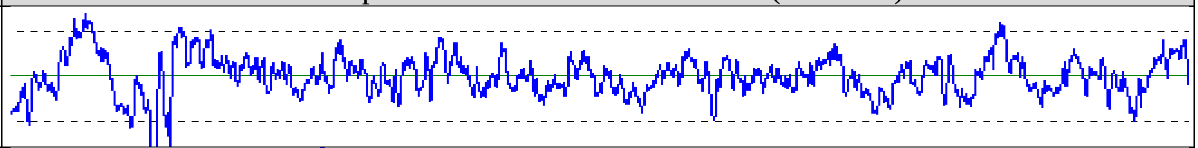
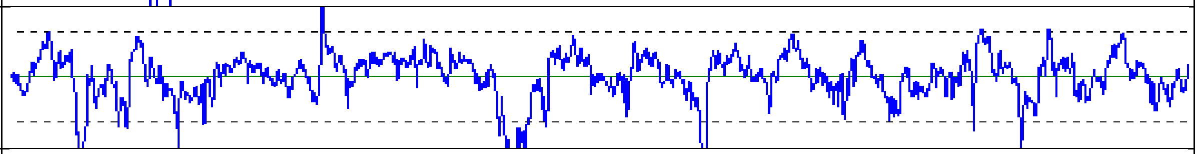
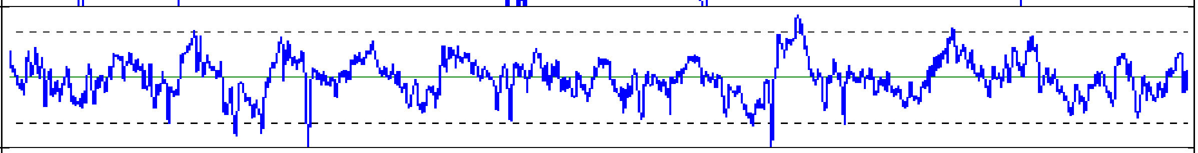
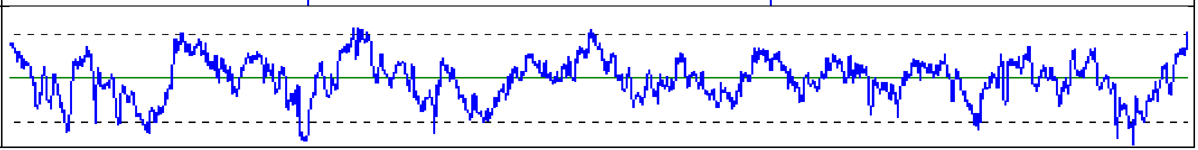
Appendix B1: Surface roughness measurement

Operator E: 23/3-2010

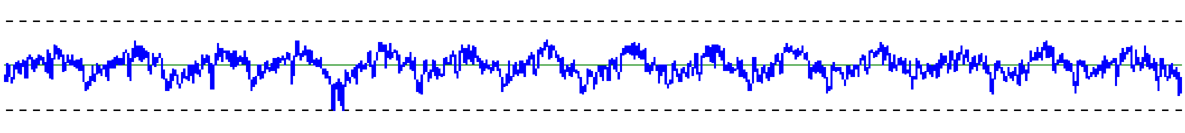
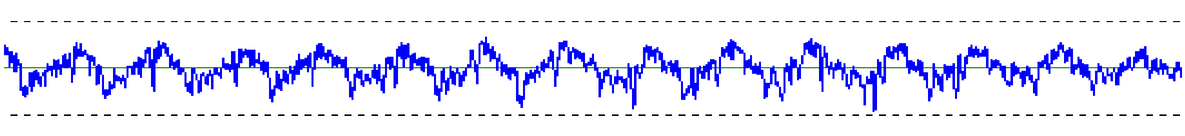
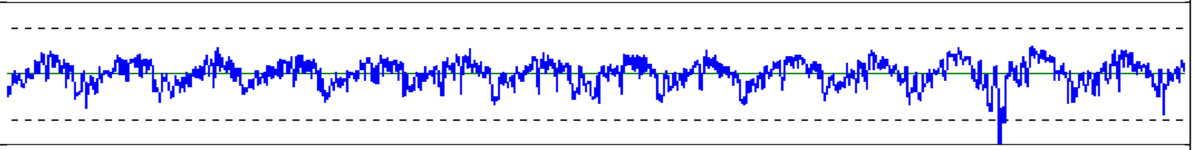
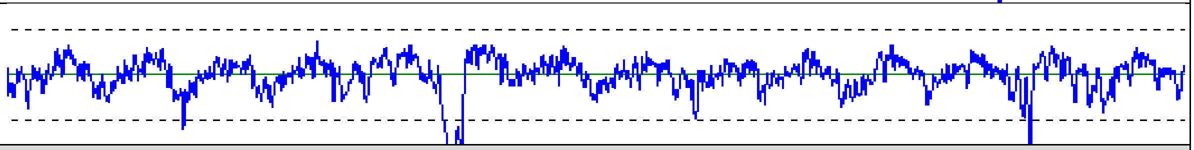
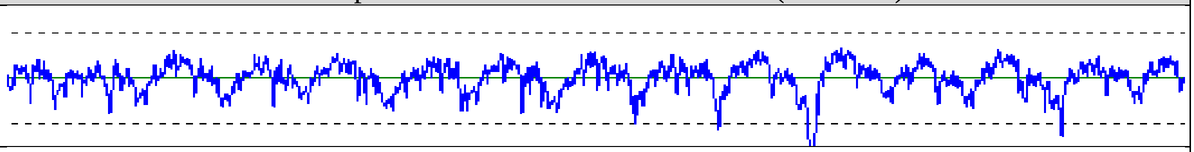
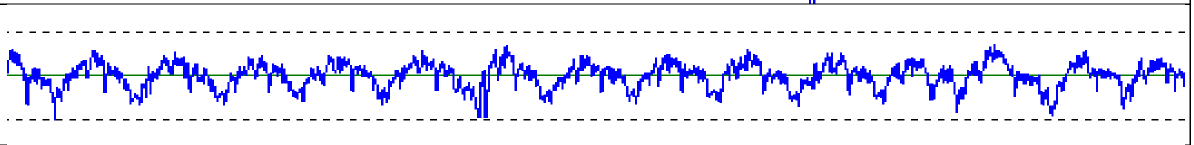
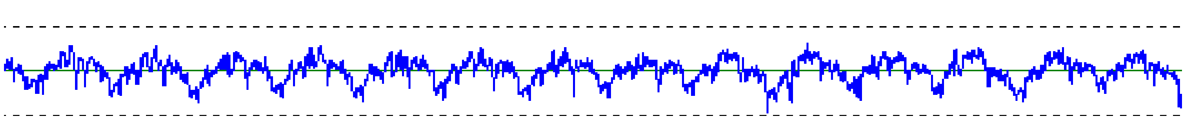
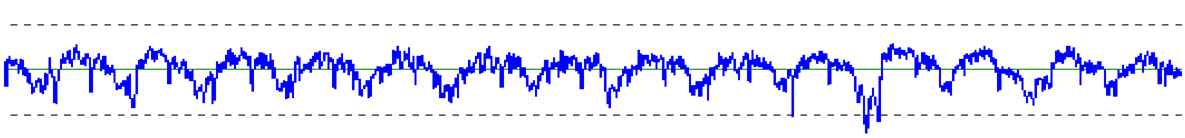
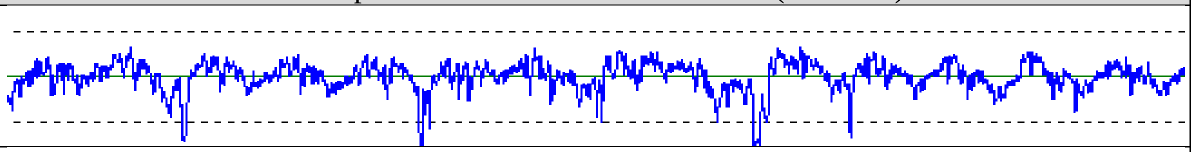
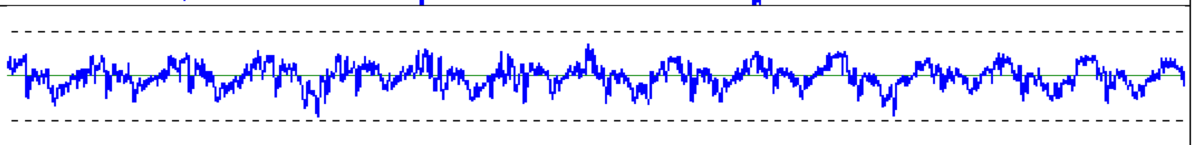
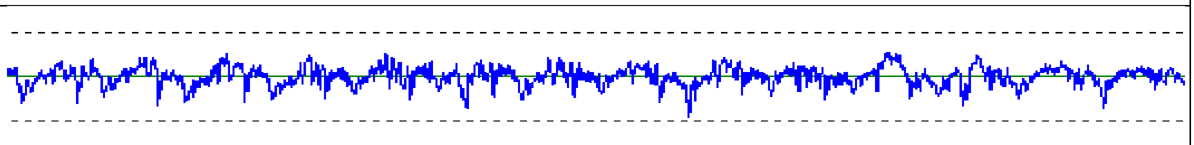
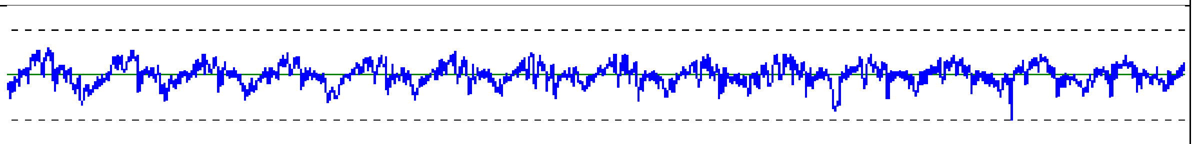
Operator E – 23/03 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

	Workpiece P1 – 1% oil concentration (P0.3/W1)
i	
j	
k	
l	
	Workpiece P2 – 1% oil concentration (P0.3/W1)
i	
j	
k	
l	
	Workpiece P3 – 1% oil concentration (P0.3/W1)
i	
j	
k	
l	

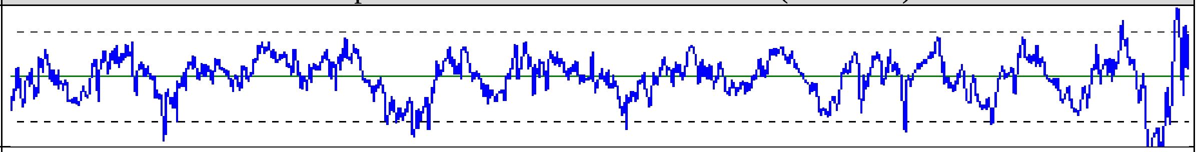
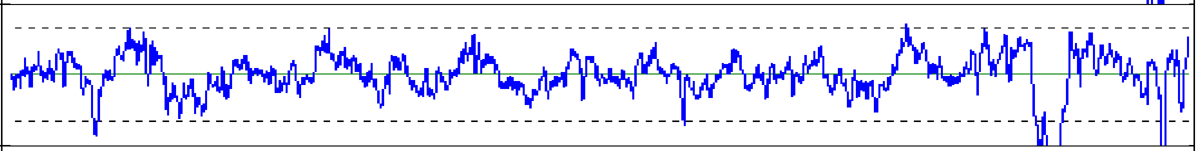
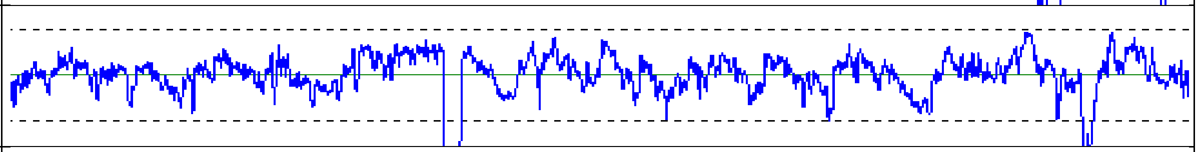
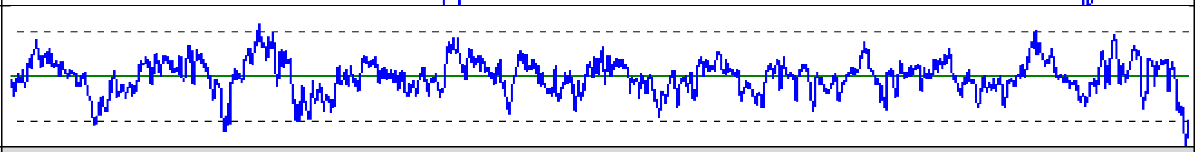
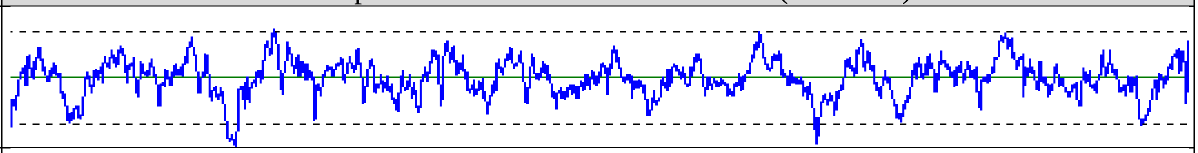
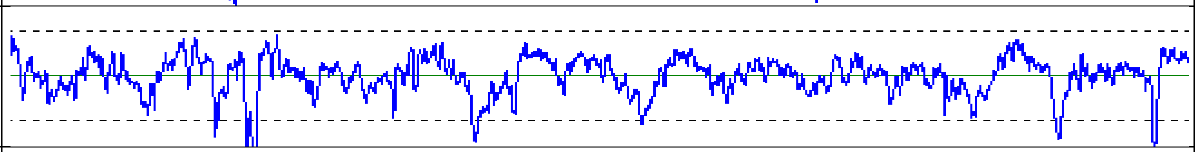
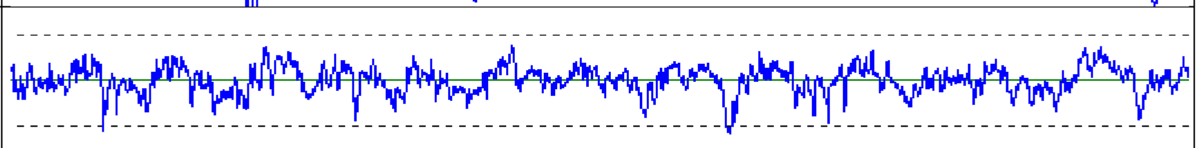
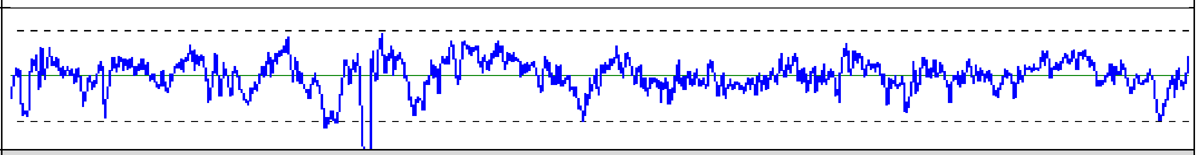
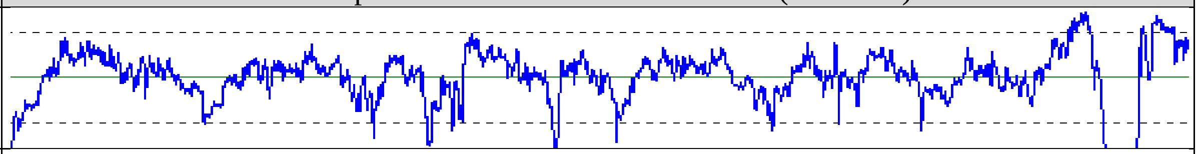
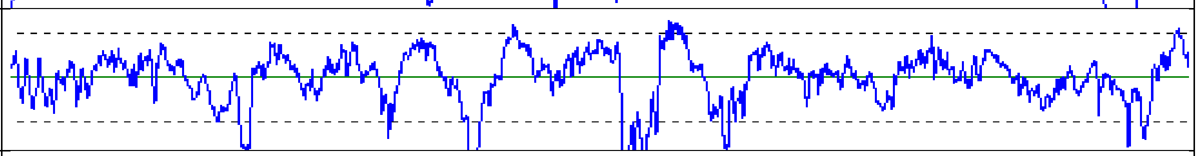
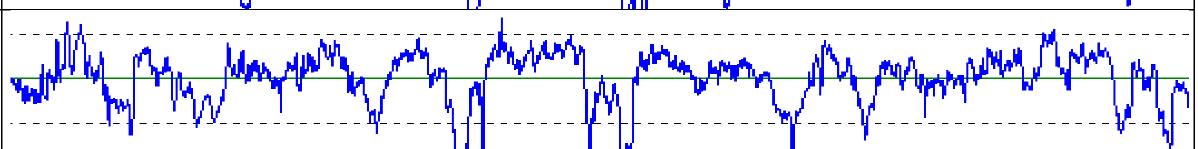
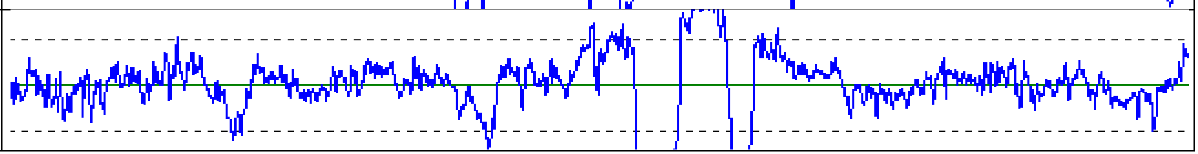
Operator E – 23/03 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

	Workpiece R1 – 1% oil concentration (R0.3/W1)
i	
j	
k	
l	
	Workpiece R2 – 1% oil concentration (R0.3/W1)
i	
j	
k	
l	
	Workpiece R3 – 1% oil concentration (R0.3/W1)
i	
j	
k	
l	

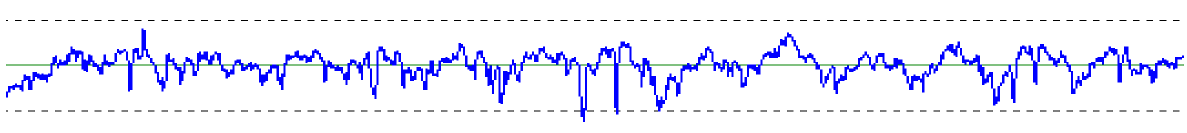
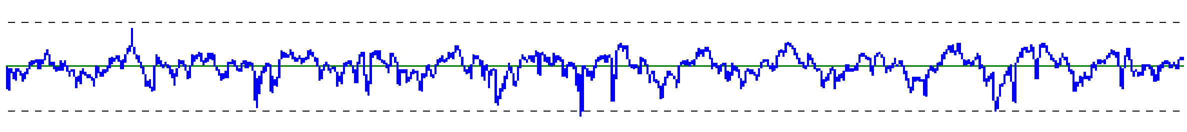
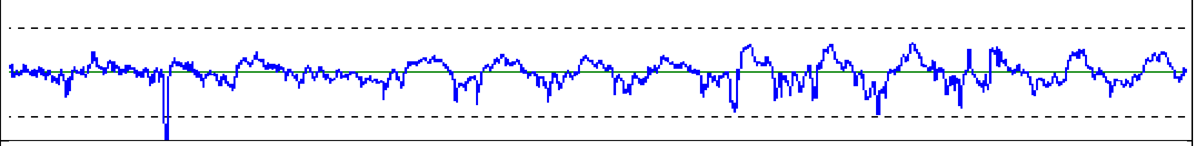
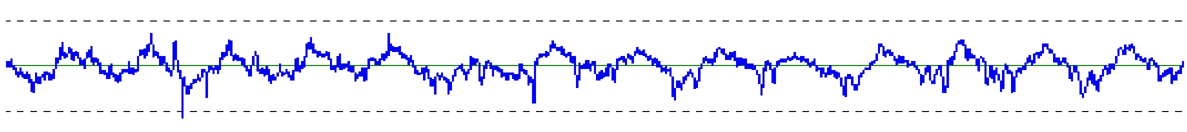
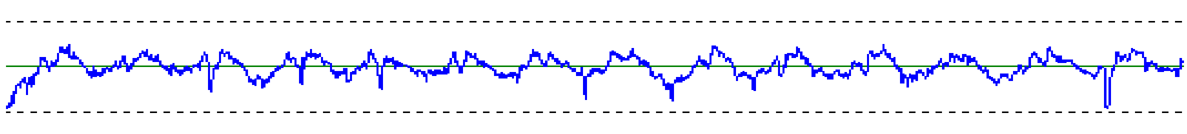
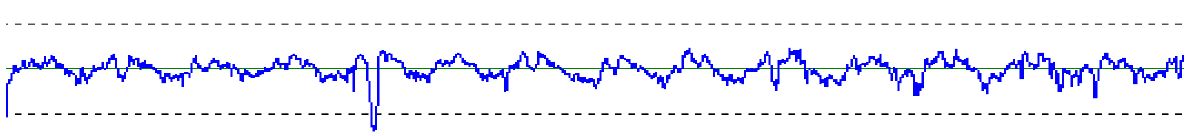
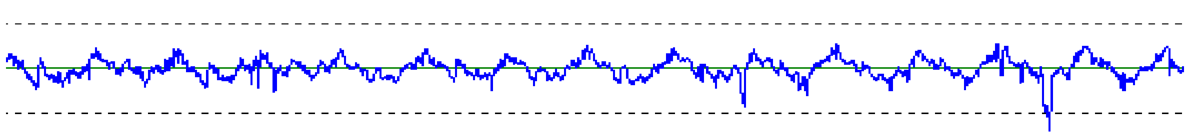
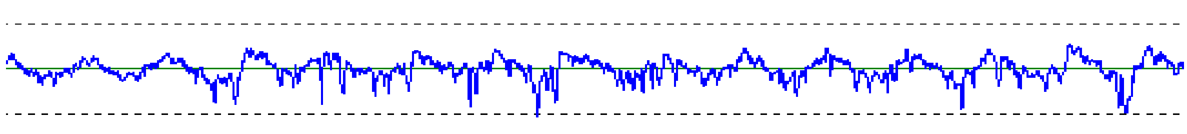
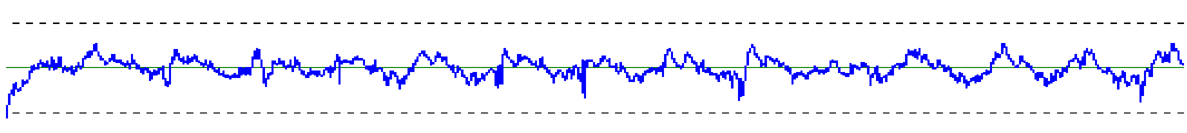
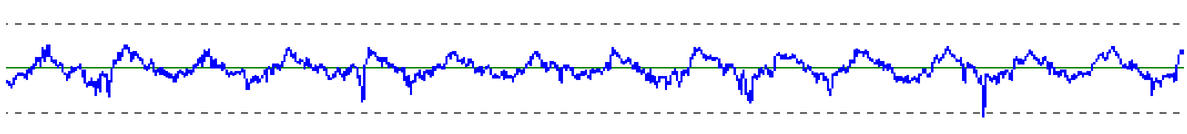
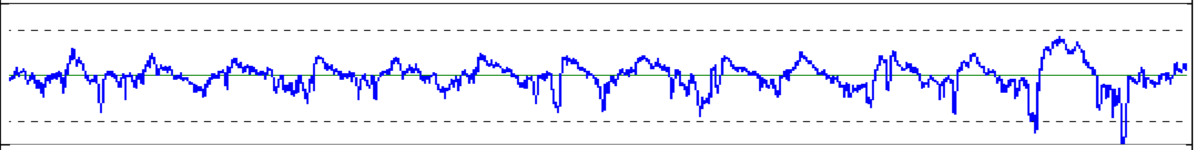
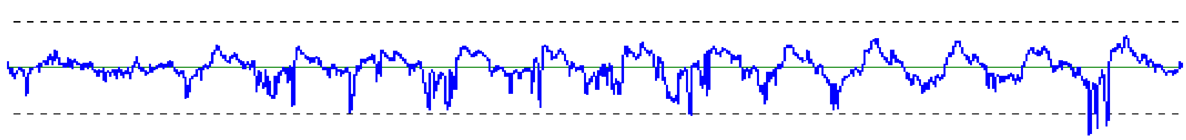
Operator E – 23/03 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

	Workpiece P1 – 10% oil concentration (P0.3/W2)
i	
j	
k	
l	
	Workpiece P2 – 10% oil concentration (P0.3/W2)
i	
j	
k	
l	
	Workpiece P3 – 10% oil concentration (P0.3/W2)
i	
j	
k	
l	

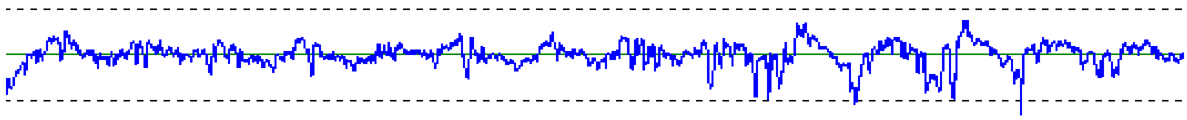
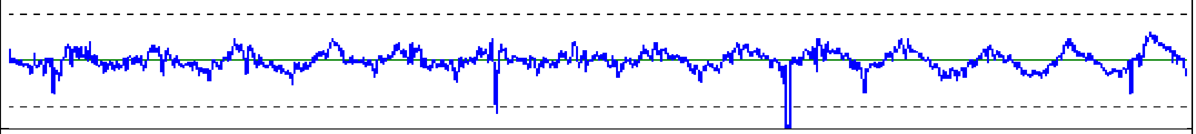
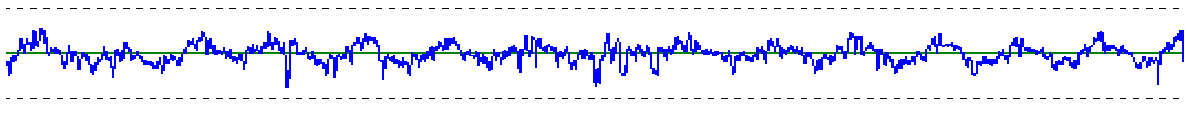
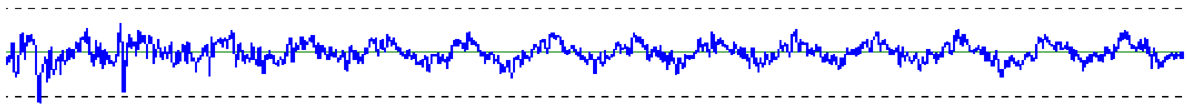
Operator E – 23/03 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

	Workpiece R1 – 10% oil concentration (R0.3/W2)
i	
j	
k	
l	
	Workpiece R2 – 10% oil concentration (R0.3/W2)
i	
j	
k	
l	
	Workpiece R3 – 10% oil concentration (R0.3/W2)
i	
j	
k	
l	

Operator E – 23/03 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

	Workpiece P1 – mineral oil (P0.3/M)
i	
j	
k	
l	
	Workpiece P2 – mineral oil (P0.3/M)
i	
j	
k	
l	
	Workpiece P3 – mineral oil (P0.3/M)
i	
j	
k	
l	

Operator E – 23/03 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

	Workpiece R1 – mineral oil (R0.3/M)
i	
j	
k	
l	
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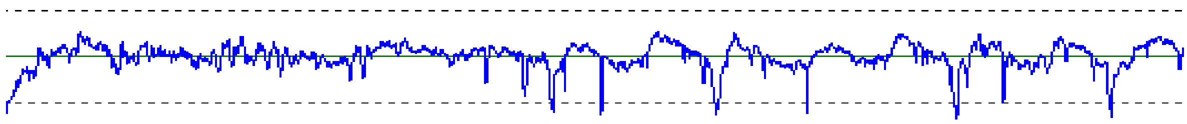
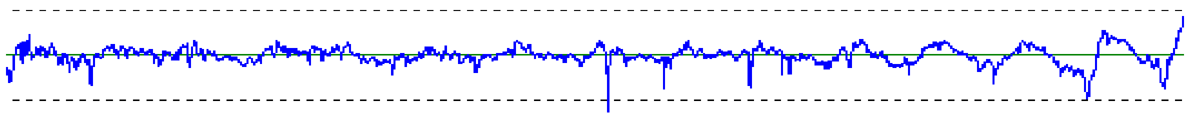
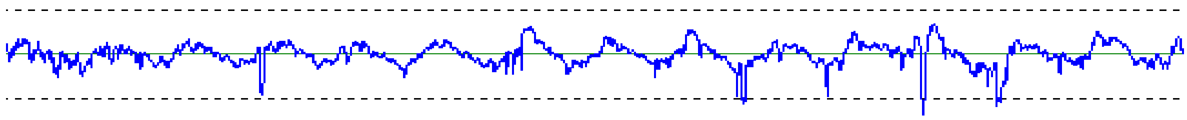
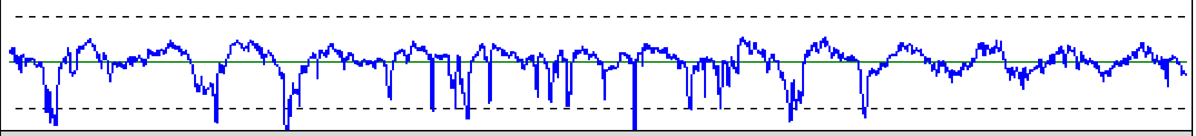
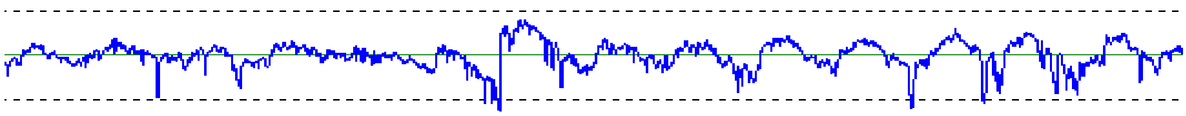
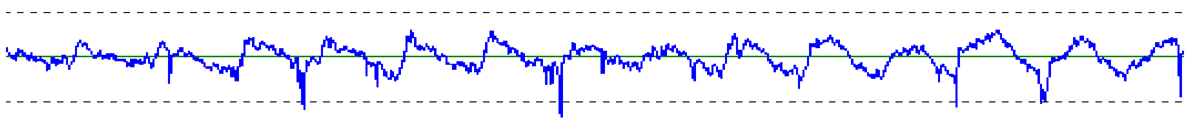
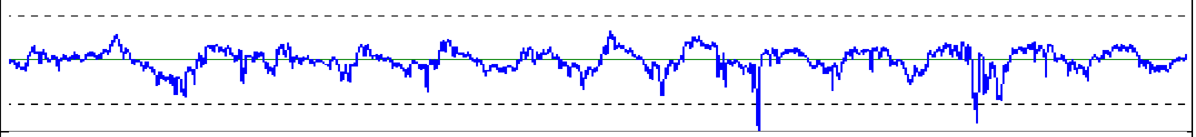
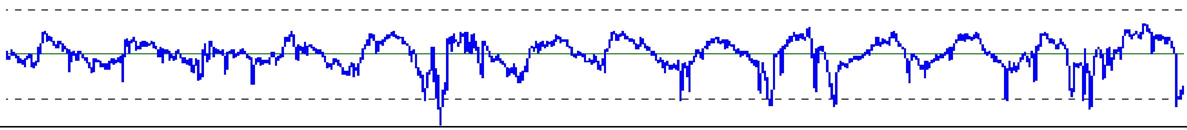
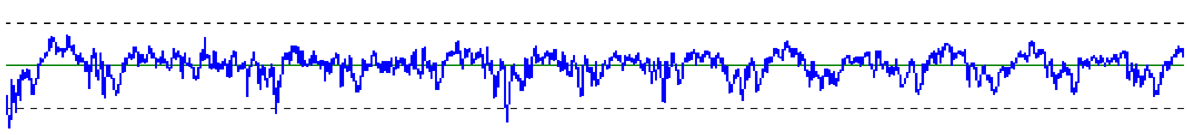
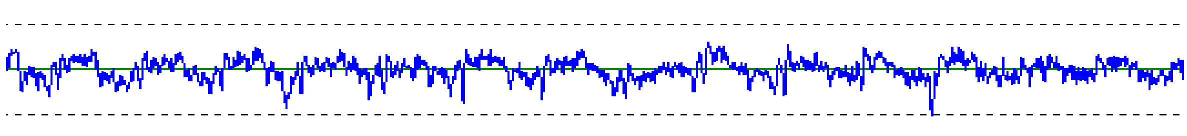
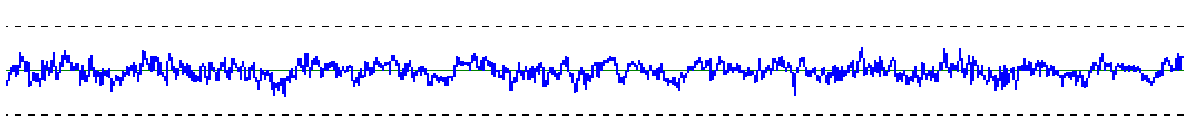
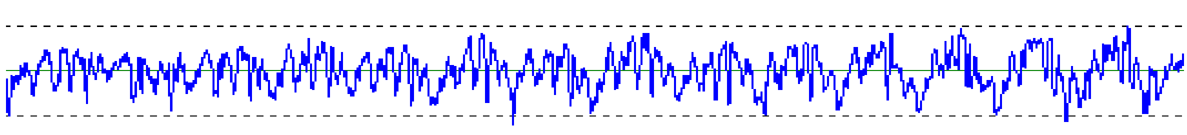
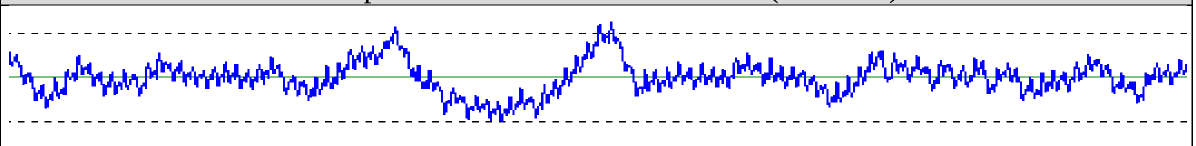
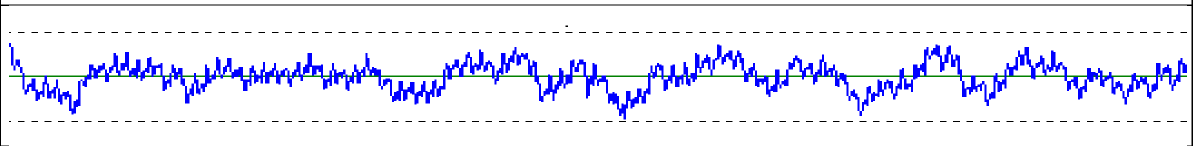
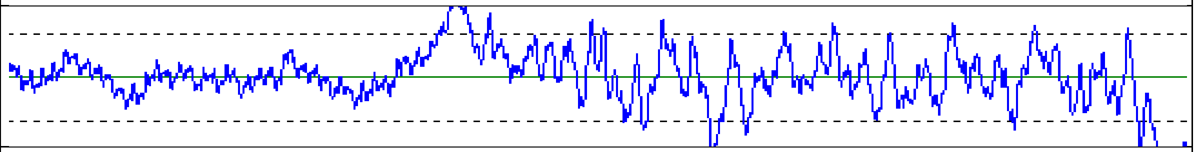
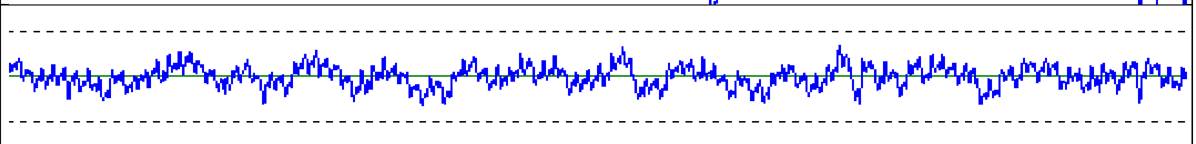
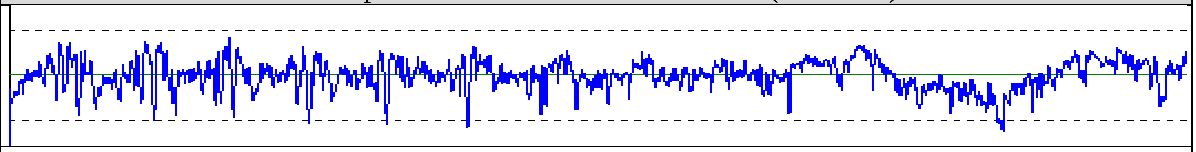
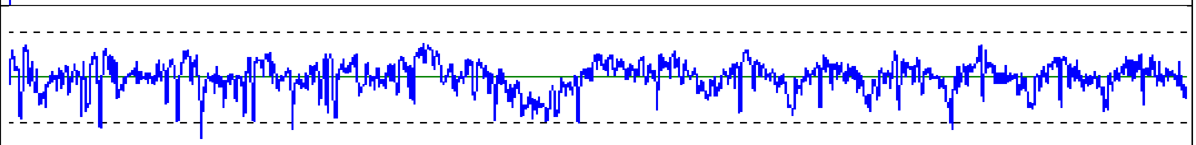
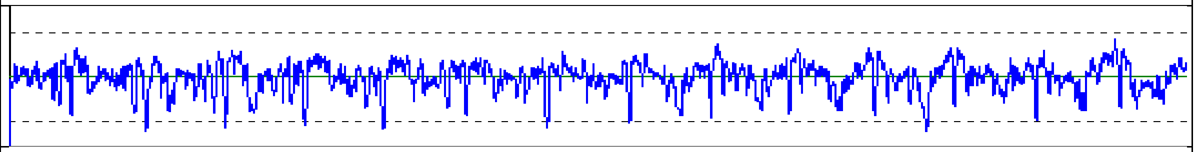
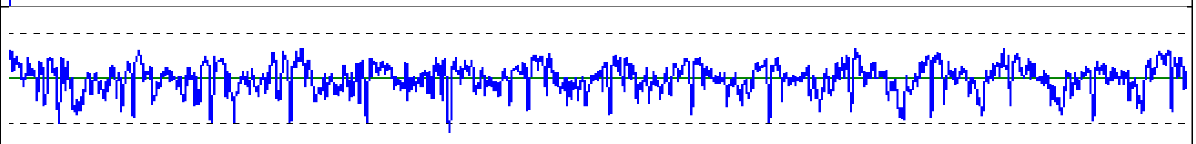
i	
j	
k	
l	
	Workpiece R3 – mineral oil (R0.3/M)
i	
j	
k	
l	

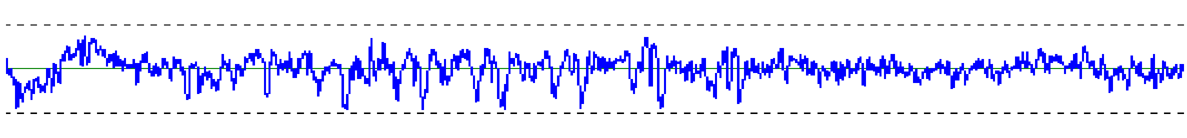
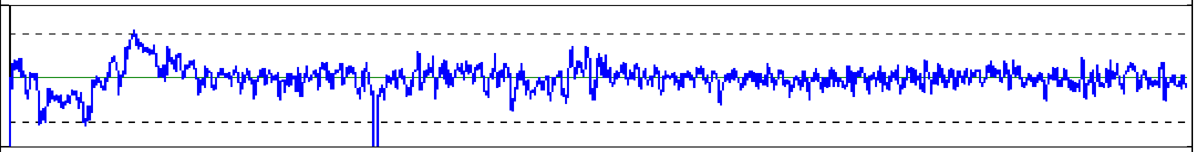
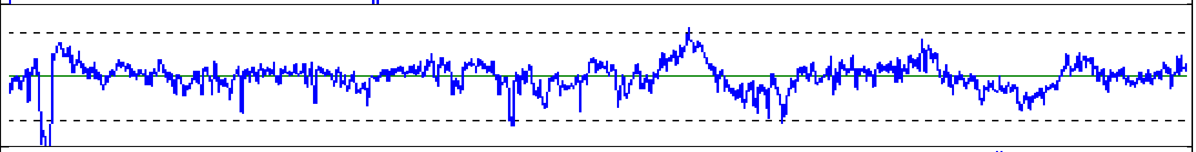
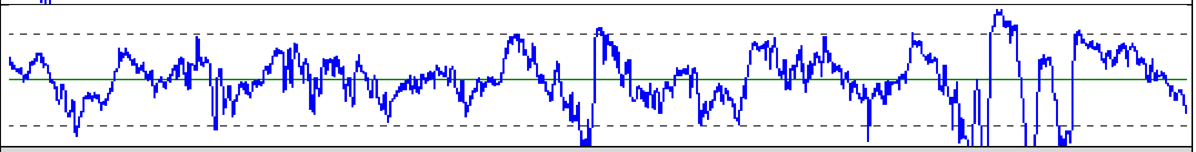
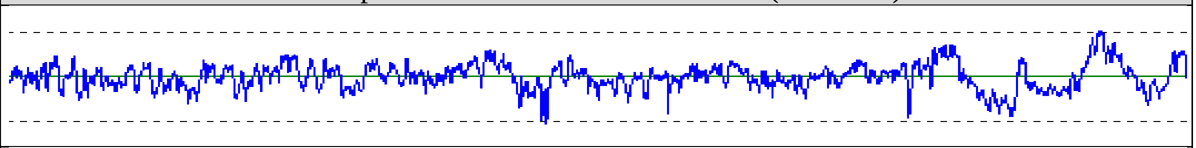
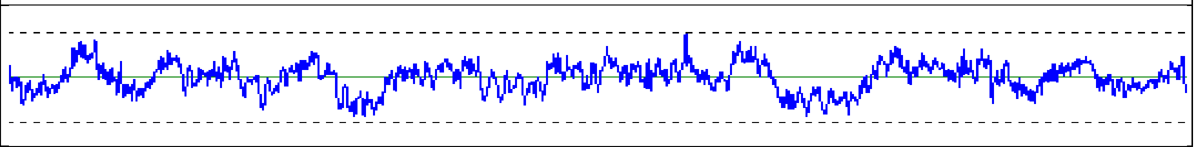
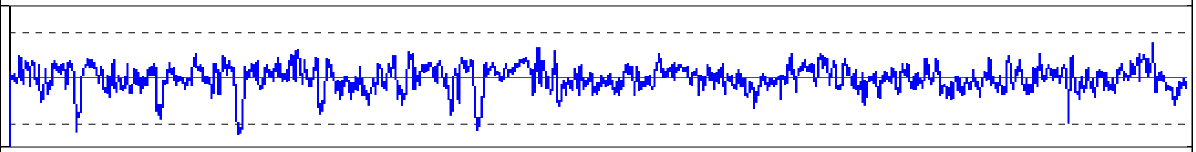
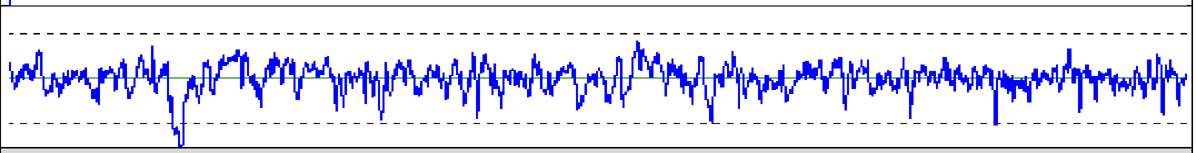
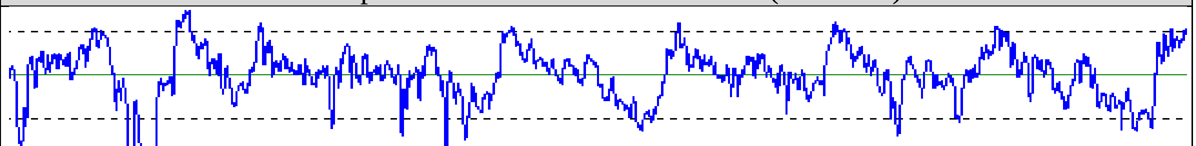
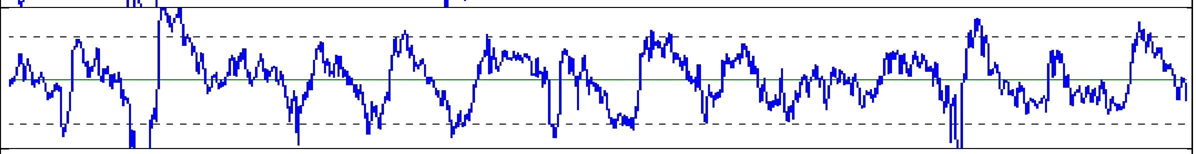
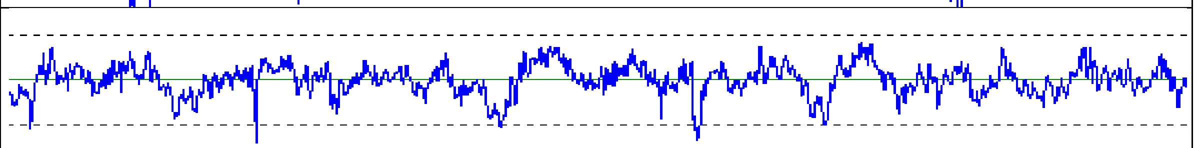
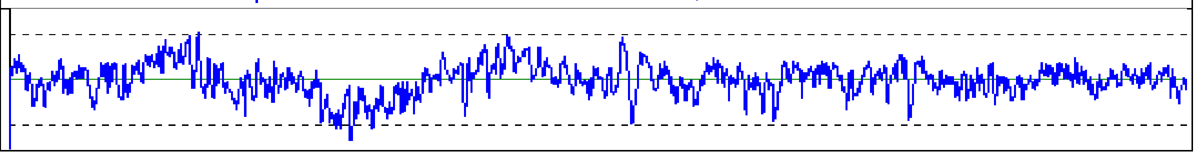
Appendix B2: Surface roughness measurement

Operator B: 12/4-2010

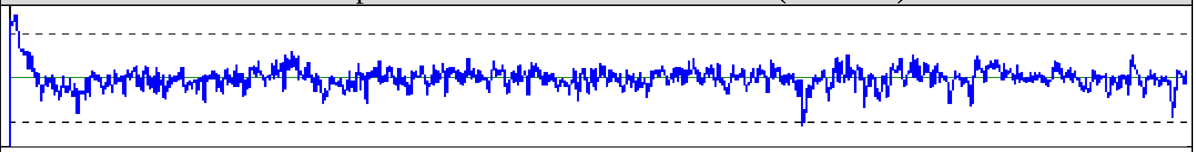
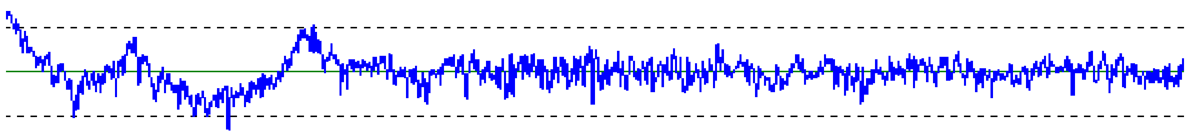
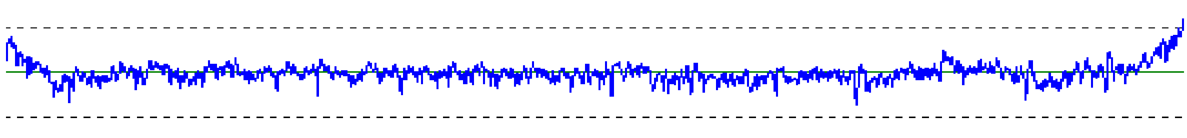
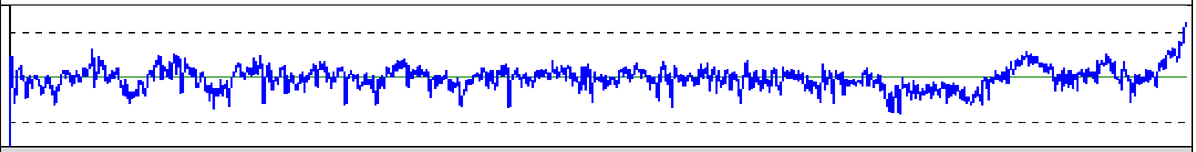
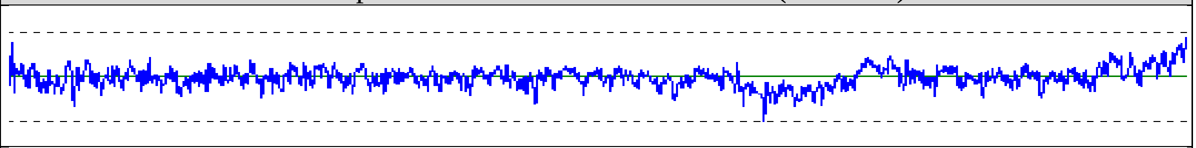
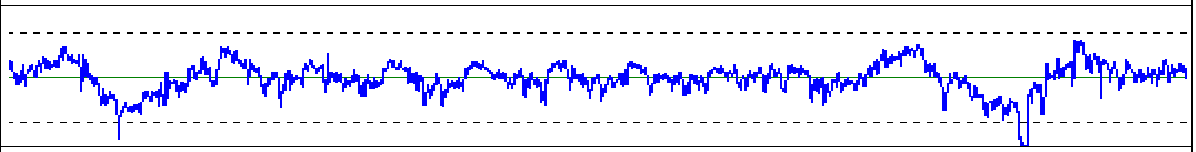
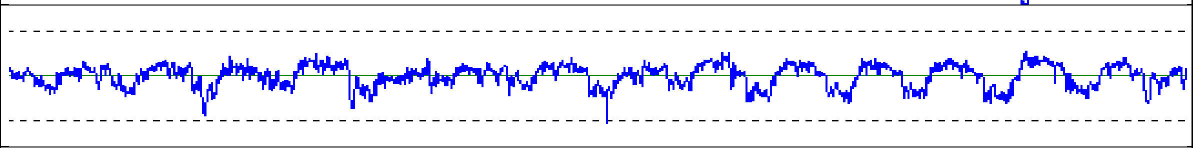
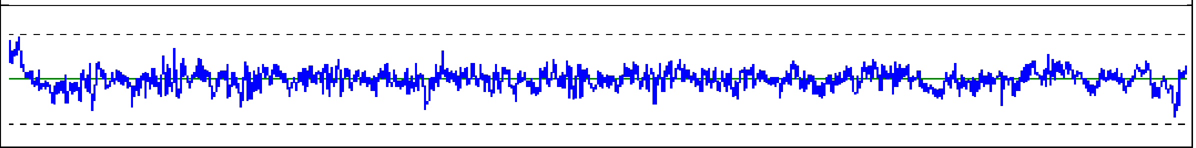
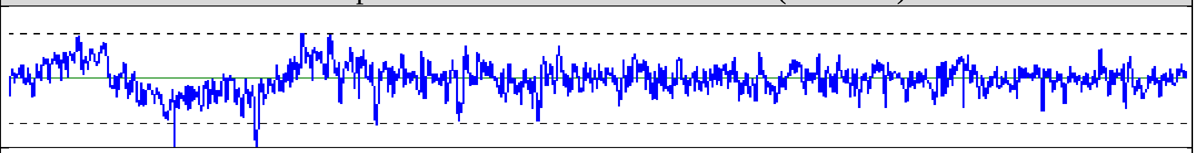
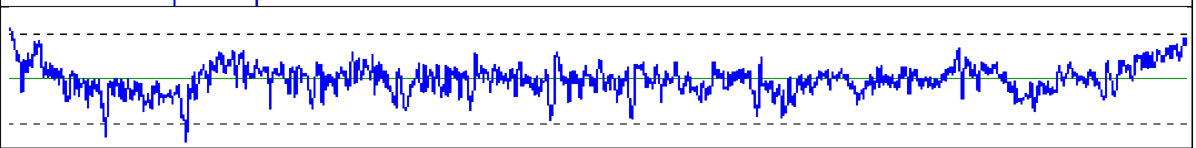
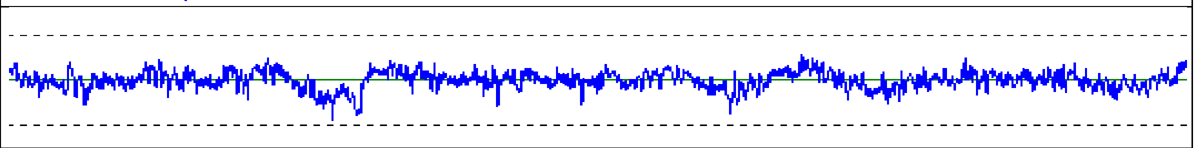
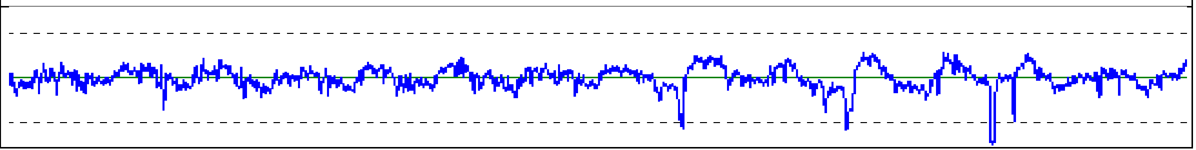
Operator B – 12/4 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

	Workpiece P1 – 1% oil concentration (P0.3/W1)
i	
j	
k	
l	
	Workpiece P2 – 1% oil concentration (P0.3/W1)
i	
j	
k	
l	
	Workpiece P3 – 1% oil concentration (P0.3/W1)
i	
j	
k	
l	

Operator B – 12/4 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

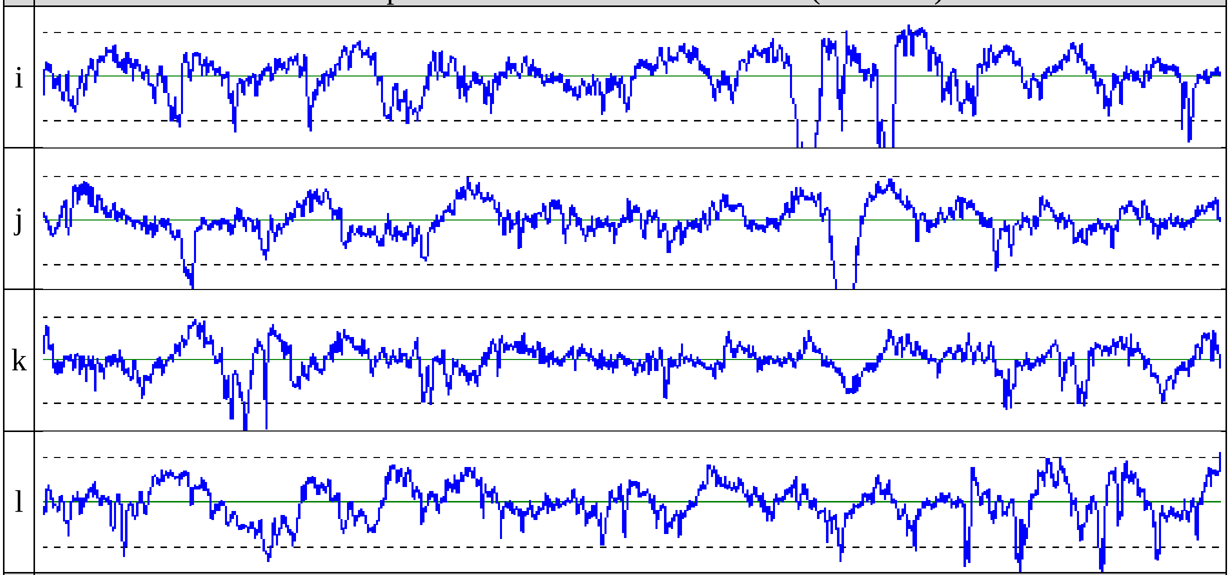
	Workpiece R1 – 1% oil concentration (R0.3/W1)
i	
j	
k	
l	
	Workpiece R2 – 1% oil concentration (R0.3/W1)
i	
j	
k	
l	
	Workpiece R3 – 1% oil concentration (R0.3/W1)
i	
j	
k	
l	

Operator B – 12/4 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

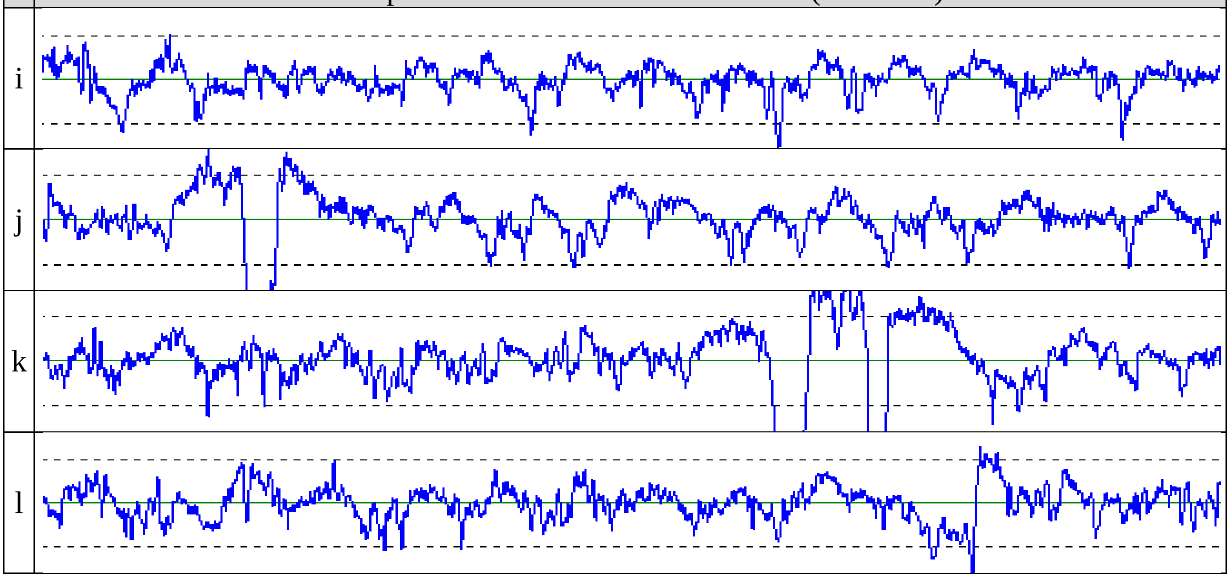
	Workpiece P1 – 10% oil concentration (P0.3/W2)
i	
j	
k	
l	
	Workpiece P2 – 10% oil concentration (P0.3/W2)
i	
j	
k	
l	
	Workpiece P3 – 10% oil concentration (P0.3/W2)
i	
j	
k	
l	

Operator B – 12/4 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

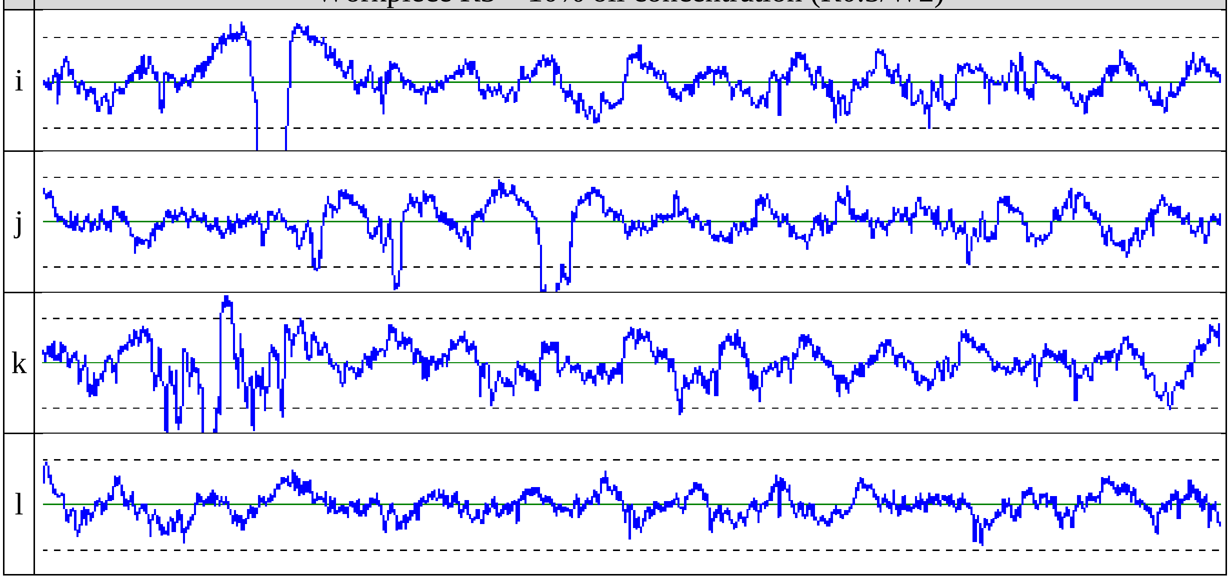
Workpiece R1 – 10% oil concentration (R0.3/W2)



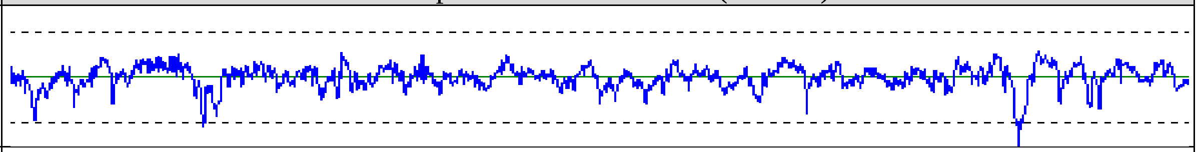
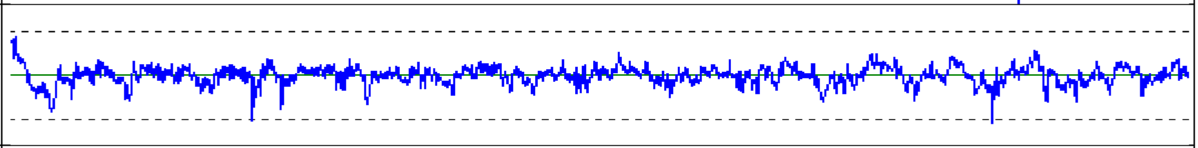
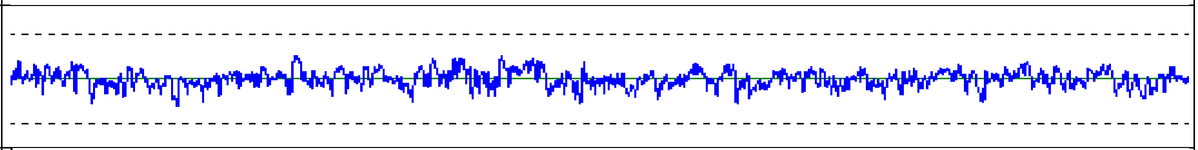
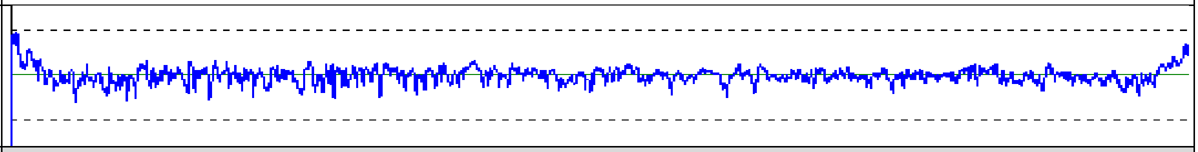
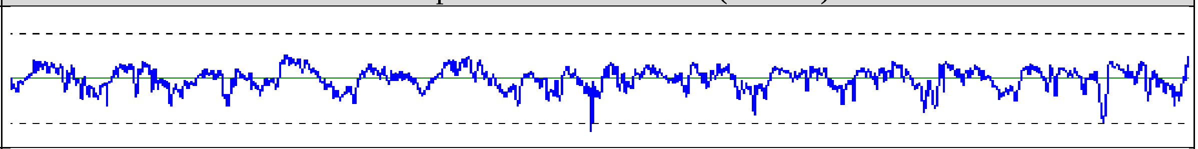
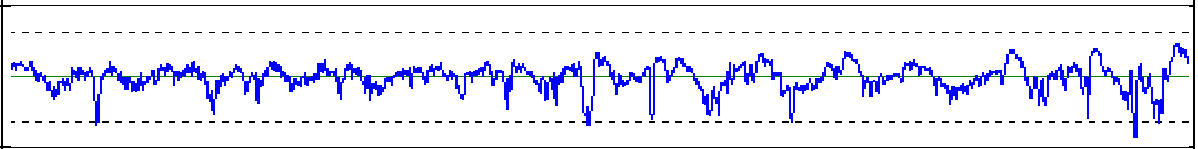
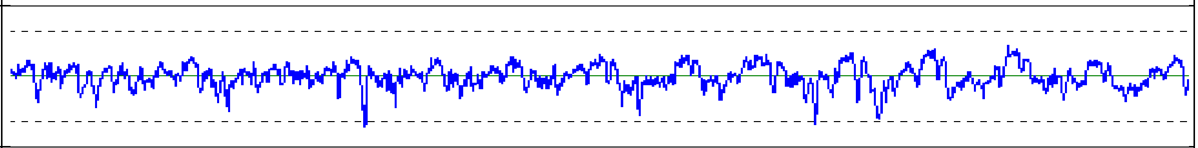
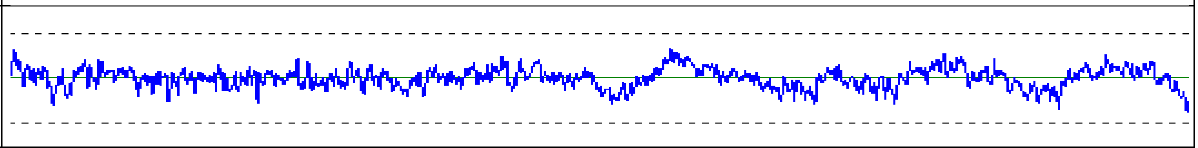
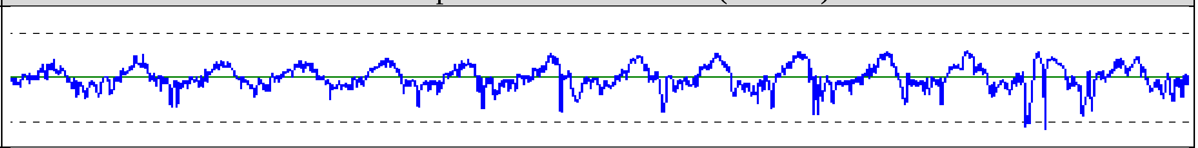
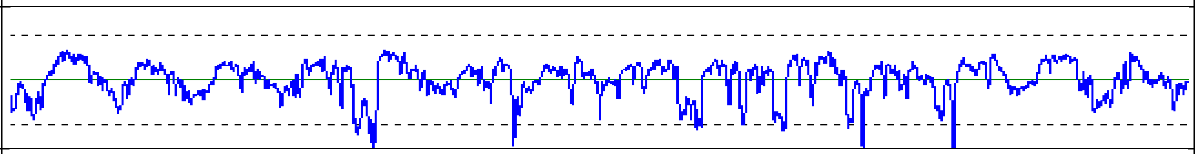
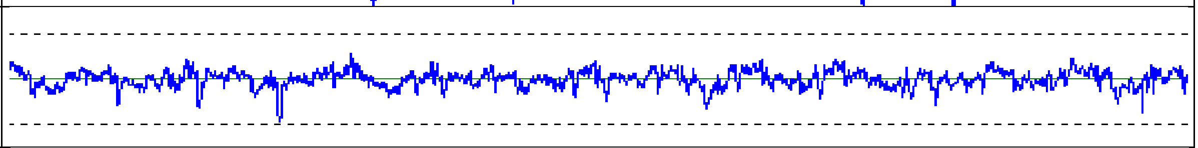
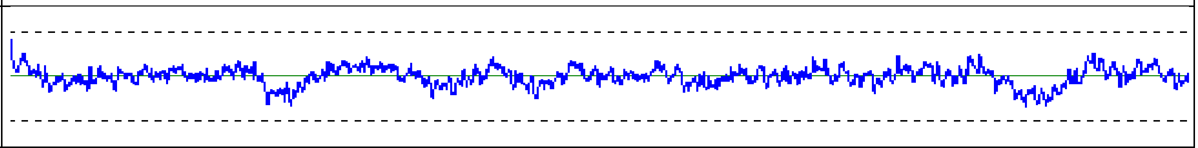
Workpiece R2 – 10% oil concentration (R0.3/W2)



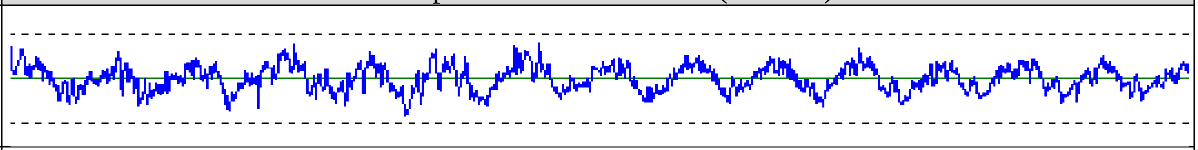
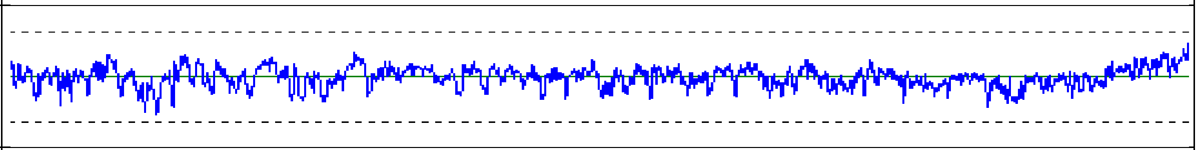
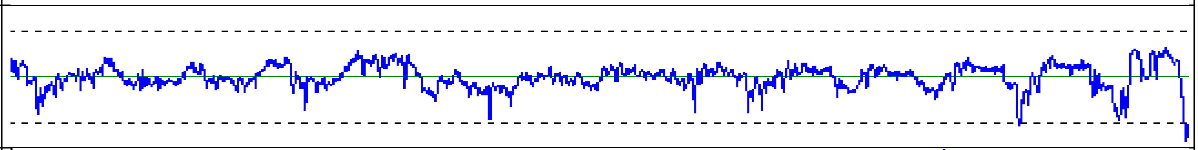
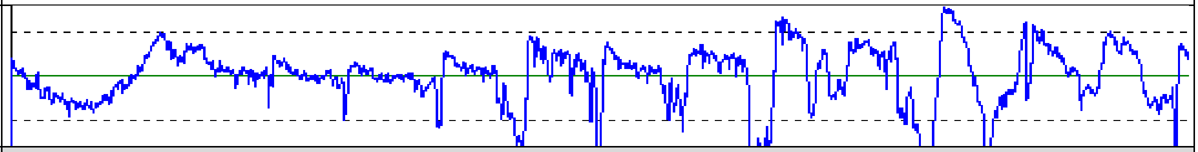
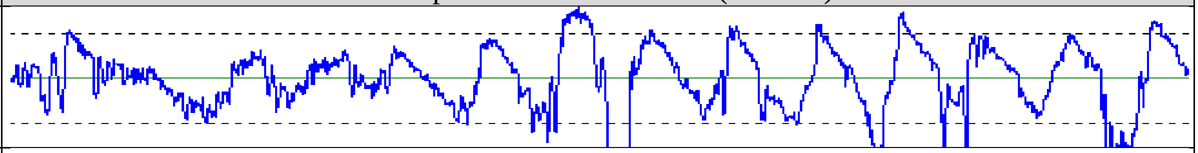
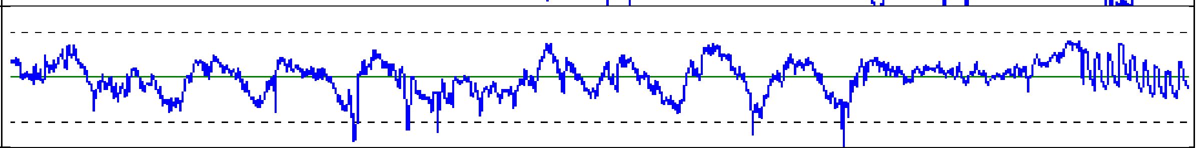
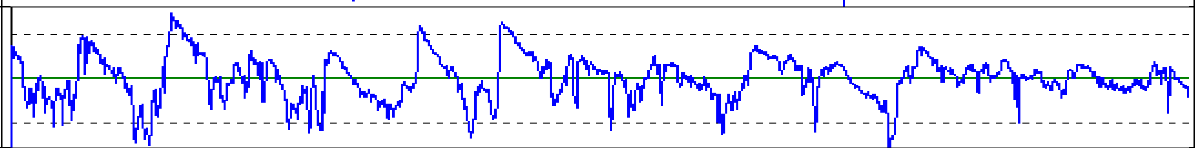
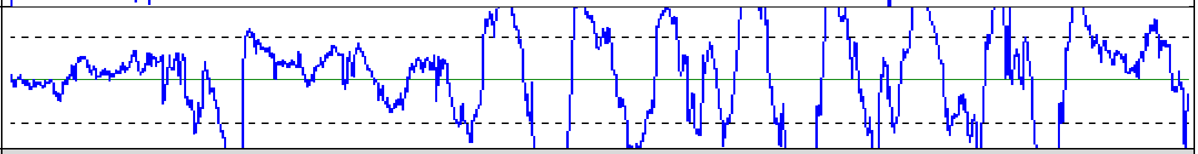
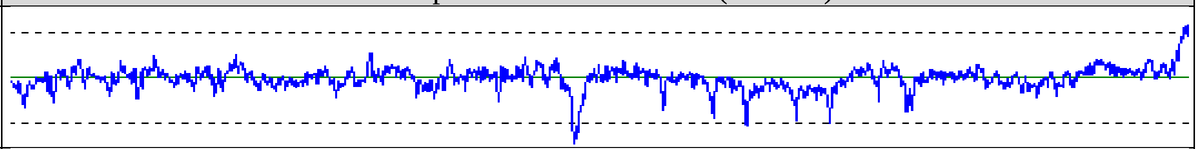
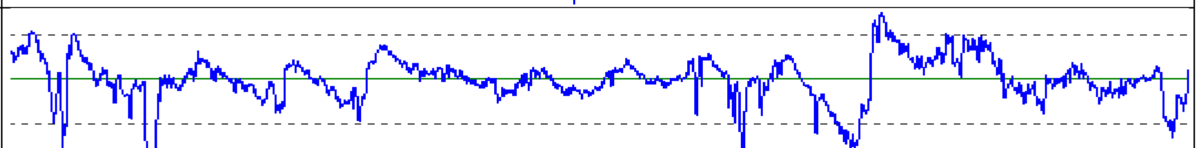
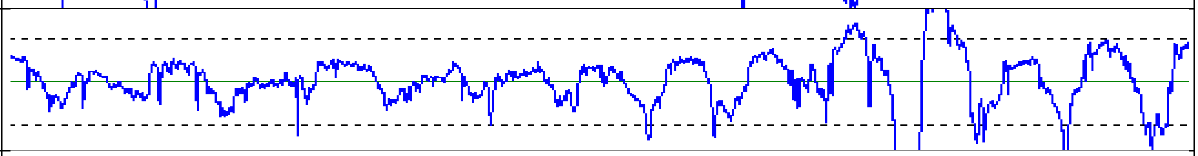
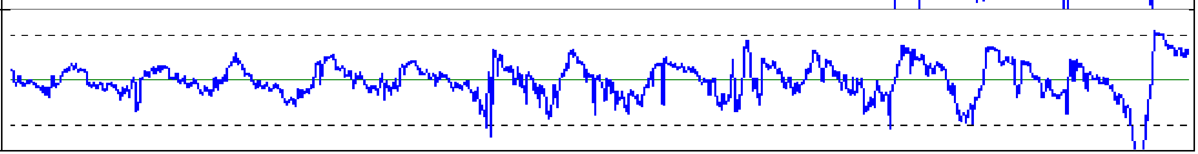
Workpiece R3 – 10% oil concentration (R0.3/W2)



Operator B – 12/4 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

	Workpiece P1 – mineral oil (P0.3/M)
i	
j	
k	
l	
	Workpiece P2 – mineral oil (P0.3/M)
i	
j	
k	
l	
	Workpiece P3 – mineral oil (P0.3/M)
i	
j	
k	
l	

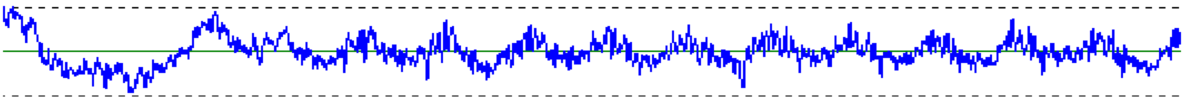
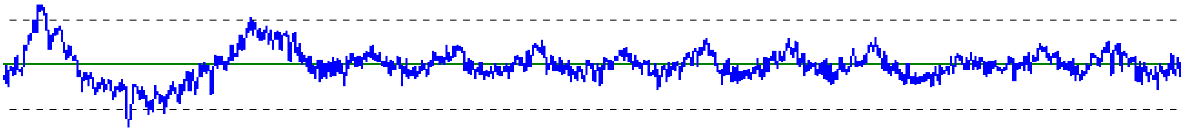
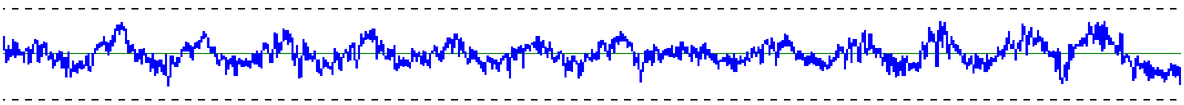
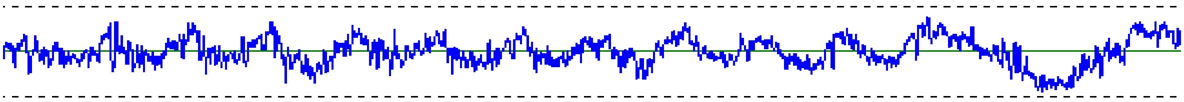
Operator B – 12/4 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

	Workpiece R1 – mineral oil (R0.3/M)
i	
j	
k	
l	
	Workpiece R2 – mineral oil (R0.3/M)
i	
j	
k	
l	
	Workpiece R3 – mineral oil (R0.3/M)
i	
j	
k	
l	

Appendix B3: Surface roughness measurement

Operator C: 19/4-2010

Operator C – 19/4 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

	Workpiece P1 – 1% oil concentration (P0.3/W1)
i	
j	
k	
l	
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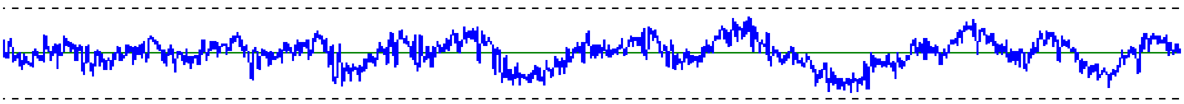
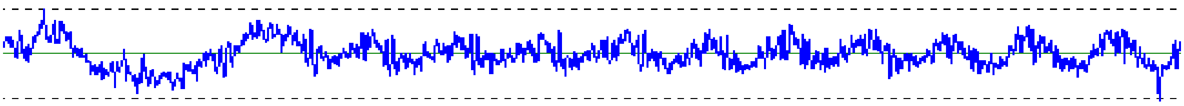
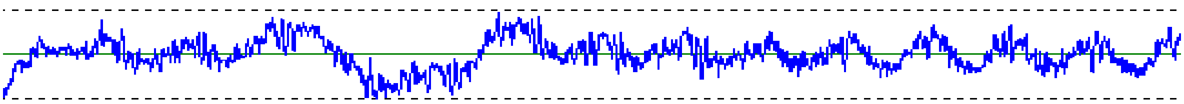
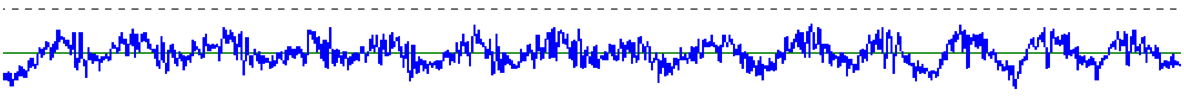
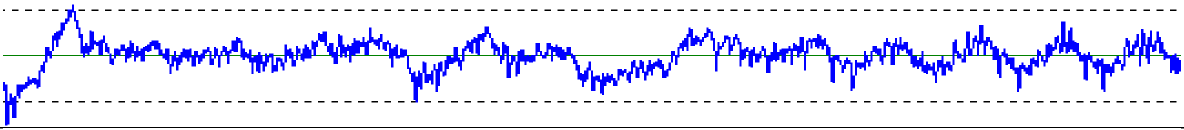
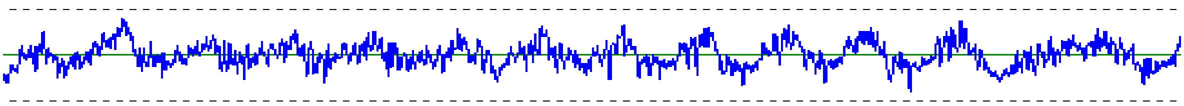
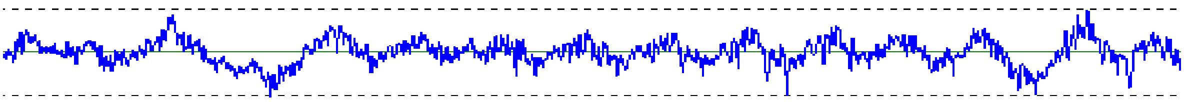
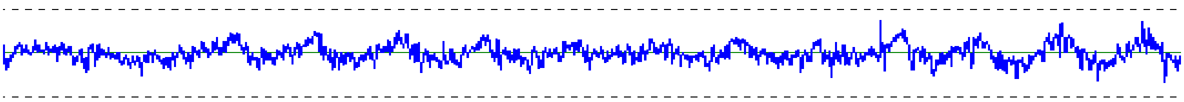
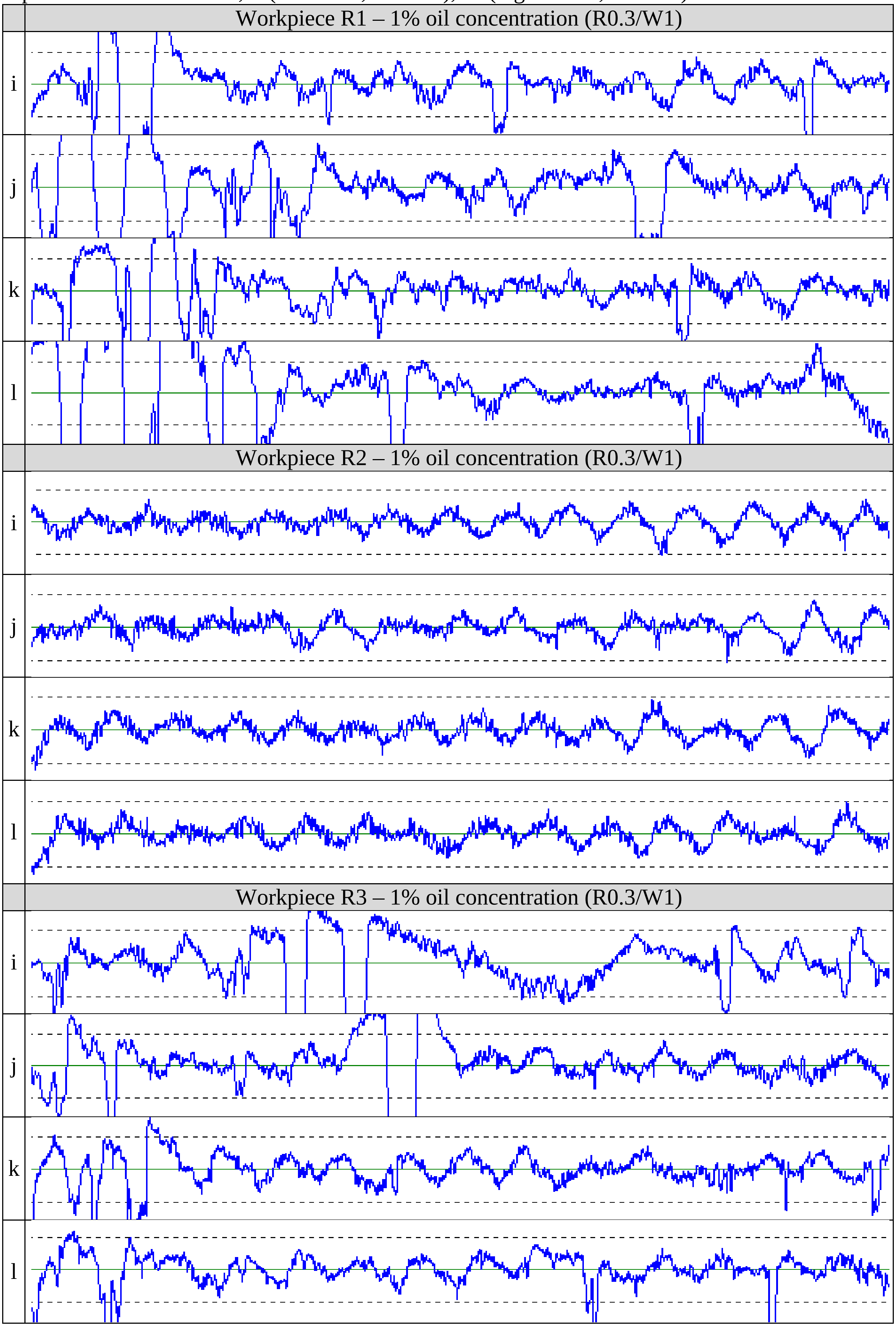
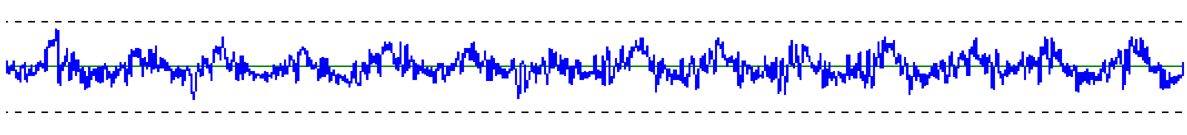
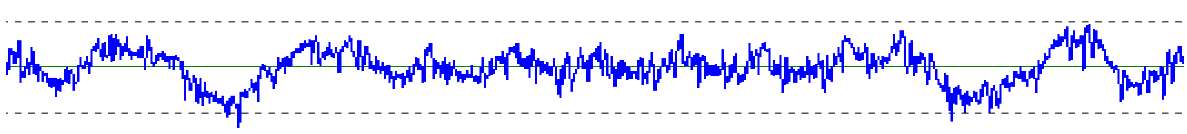
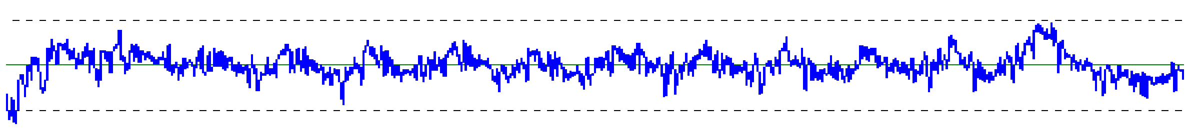
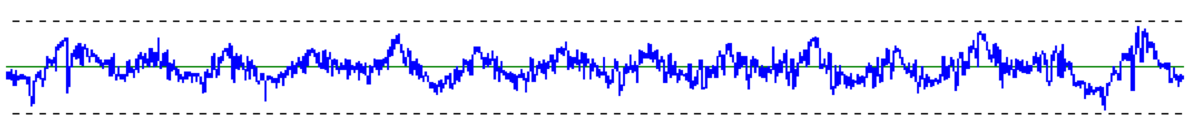
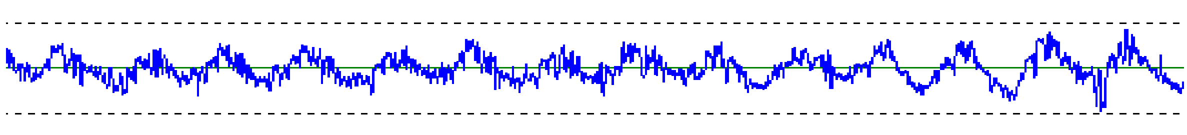
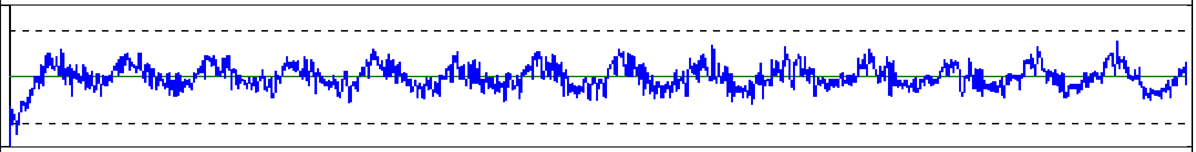
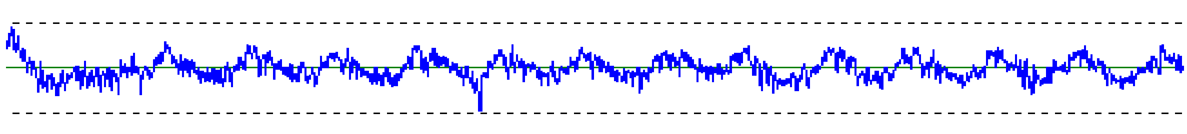
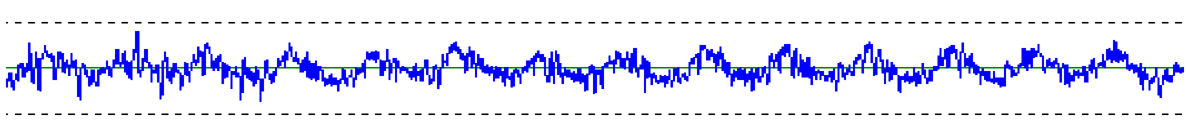
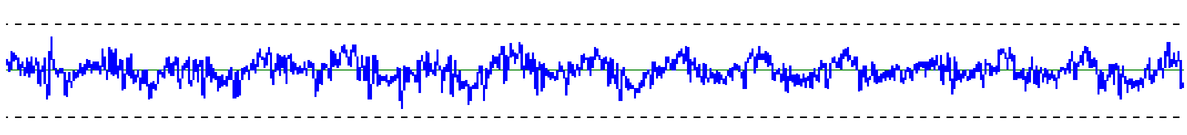
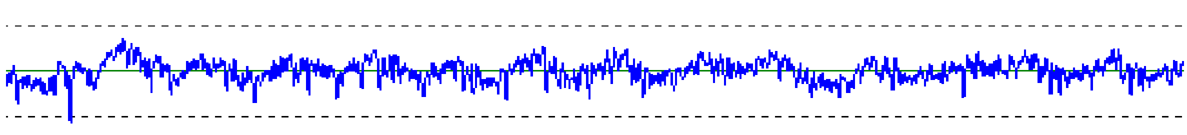
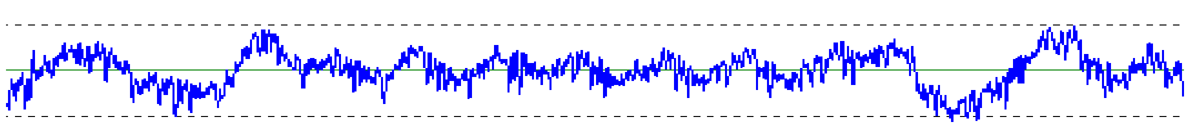
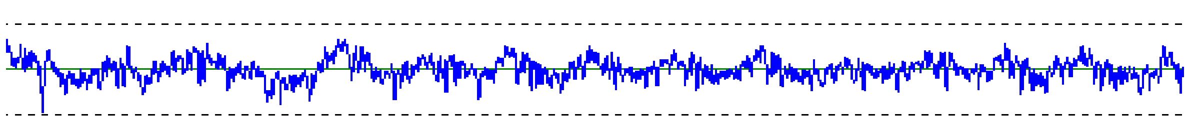
i	
j	
k	
l	
	Workpiece P3 – 1% oil concentration (P0.3/W1)
i	
j	
k	
l	

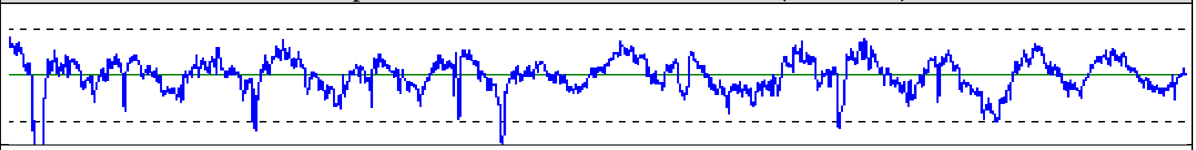
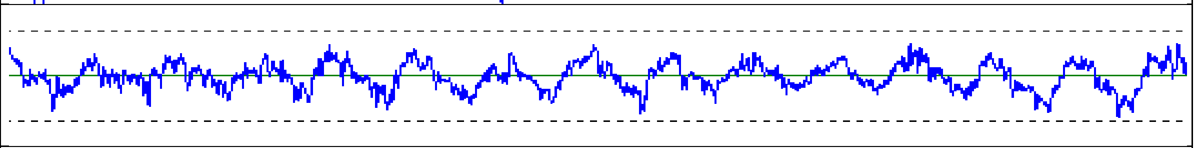
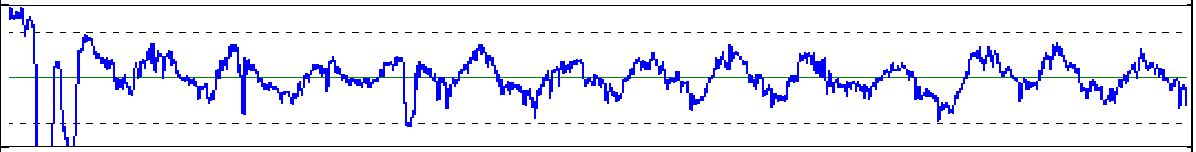
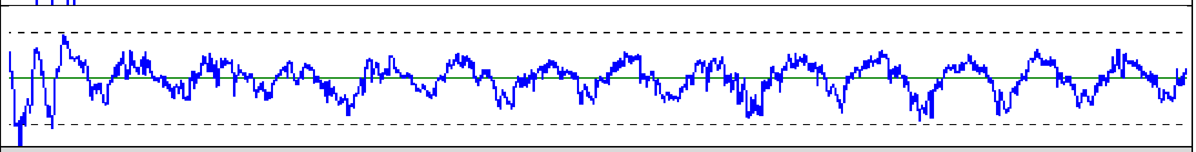
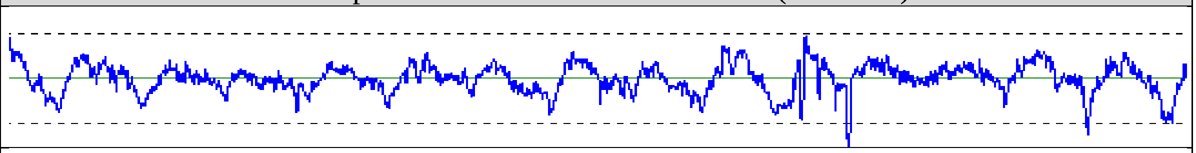
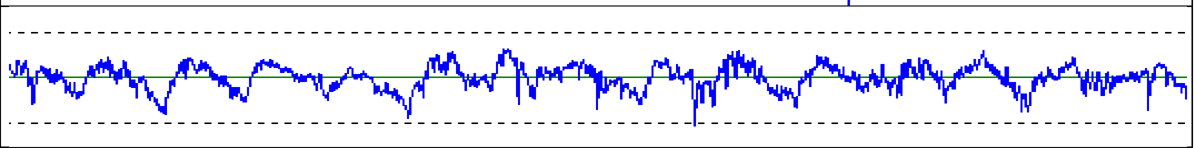
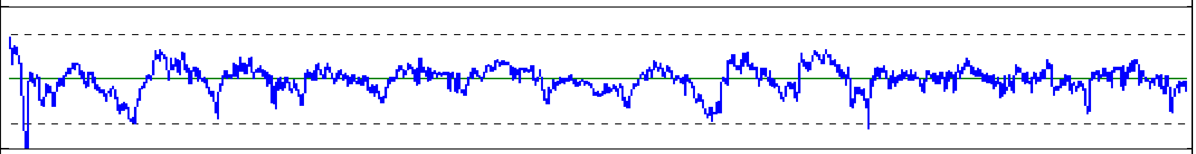
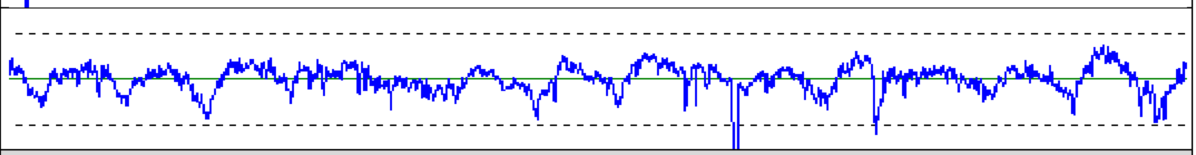
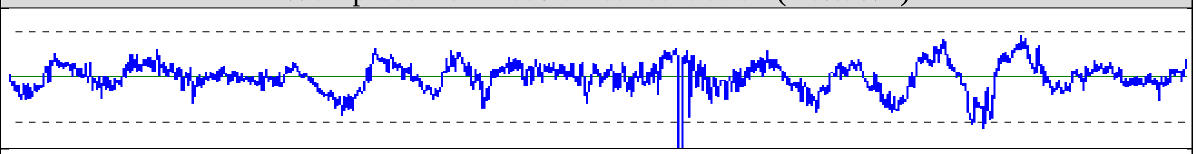
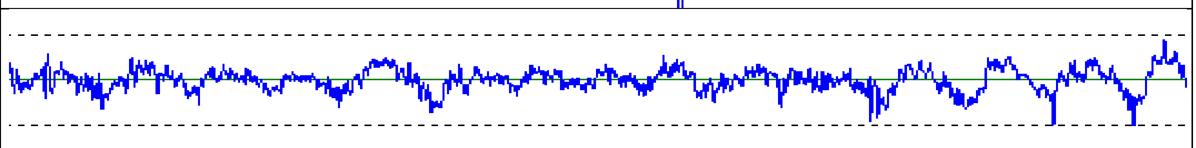
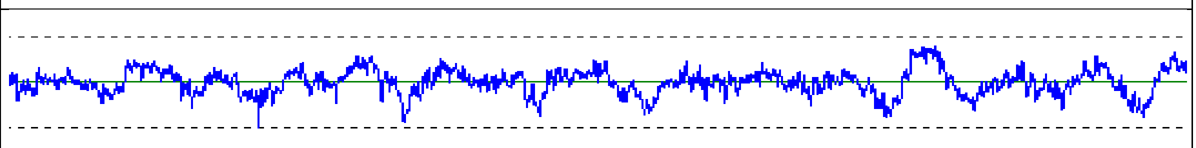
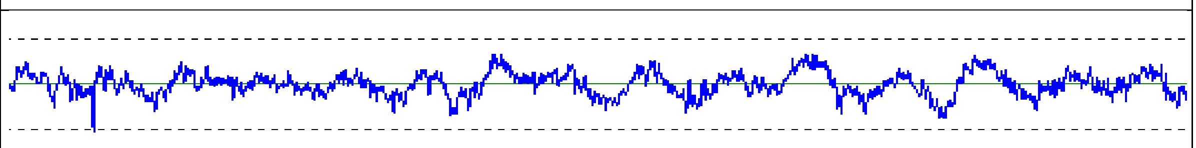
Operator C – 19/4 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)



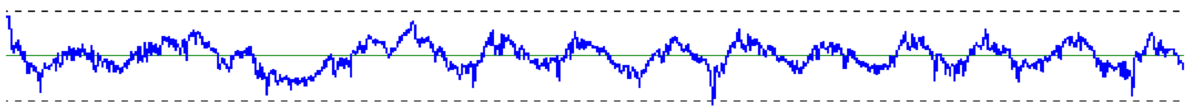
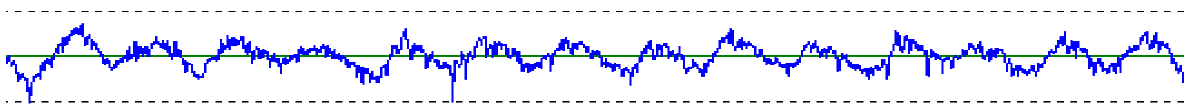
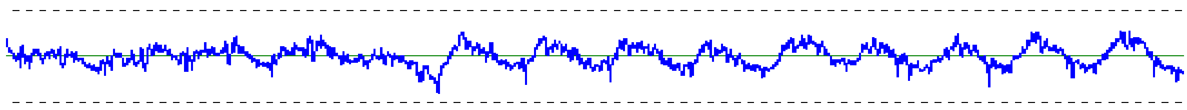
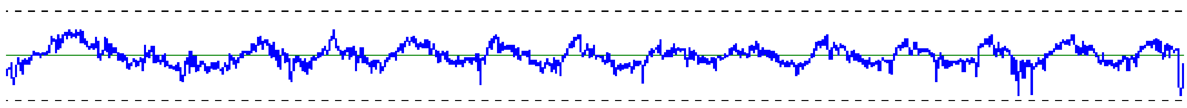
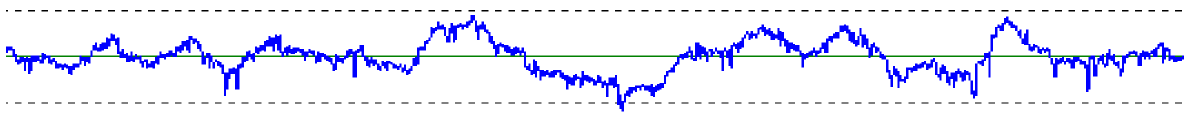
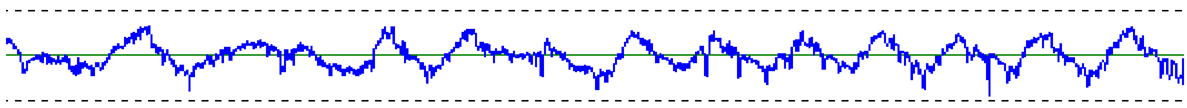
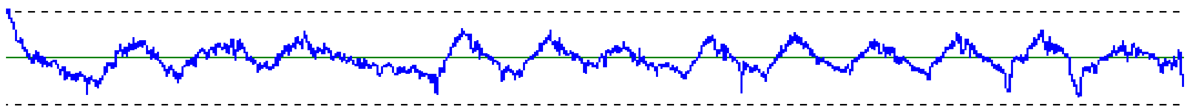
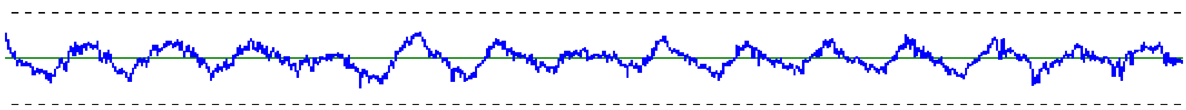
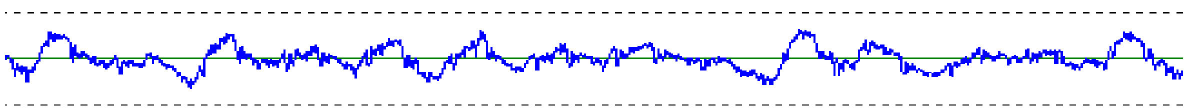
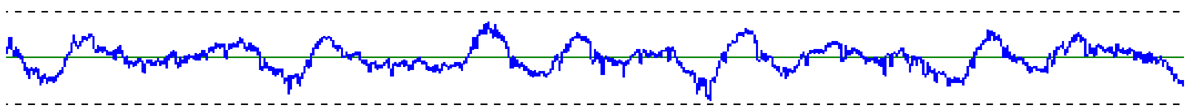
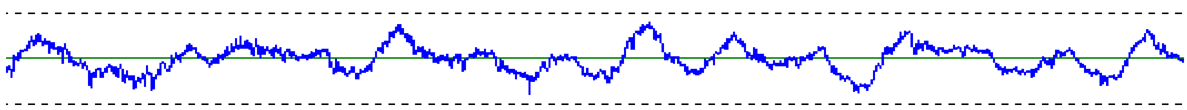
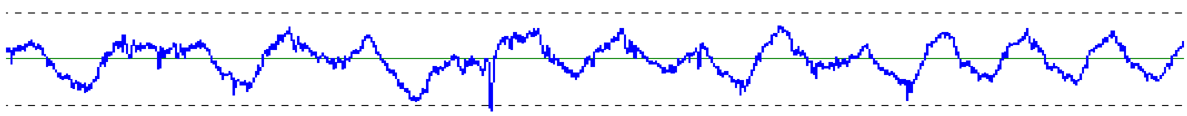
Operator C – 19/4 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

	Workpiece P1 – 10% oil concentration (P0.3/W2)
i	
j	
k	
l	
	Workpiece P2 – 10% oil concentration (P0.3/W2)
i	
j	
k	
l	
	Workpiece P3 – 10% oil concentration (P0.3/W2)
i	
j	
k	
l	

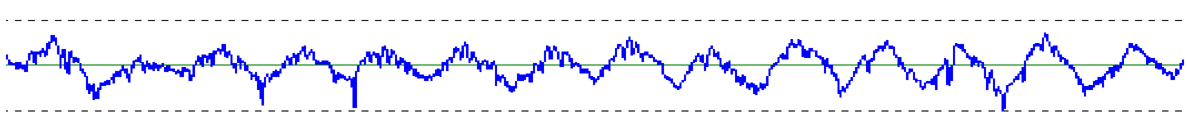
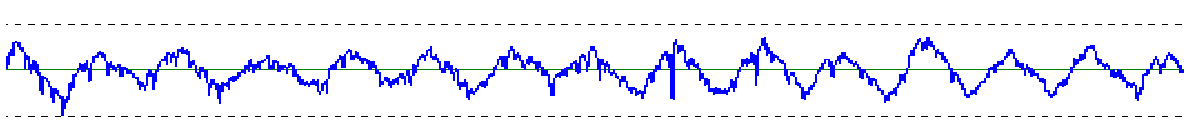
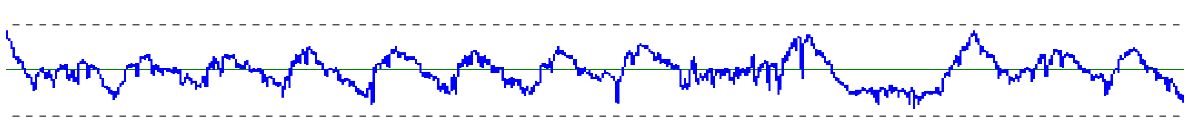
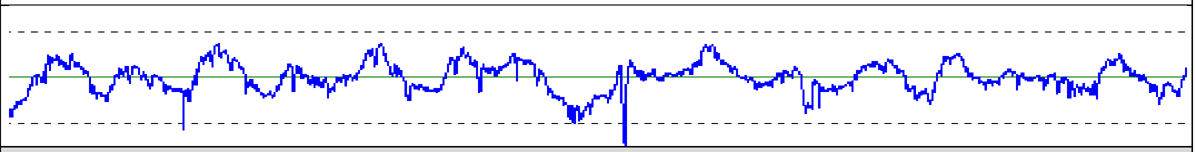
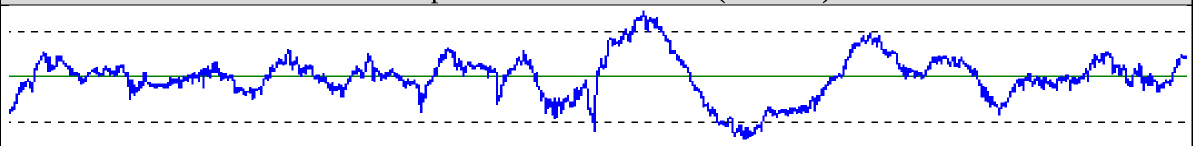
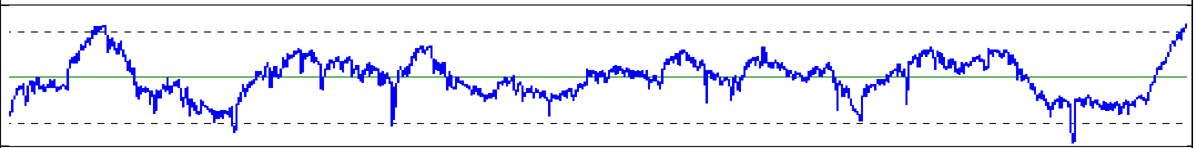
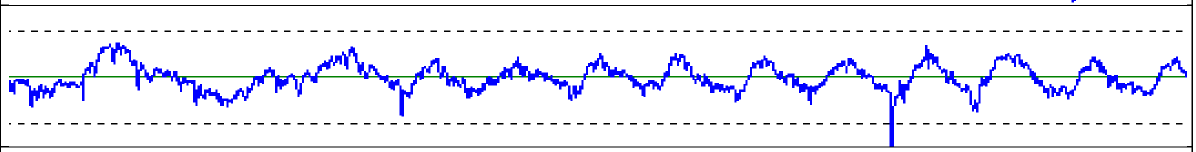
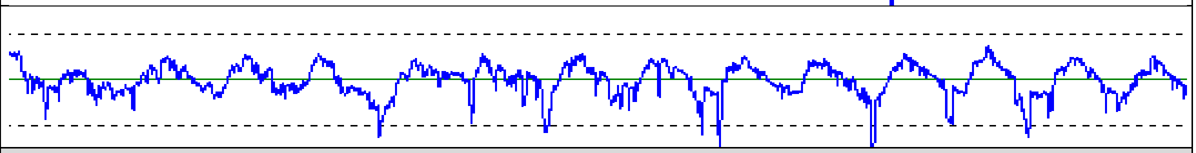
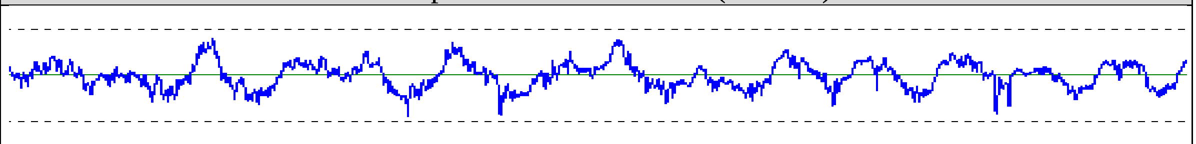
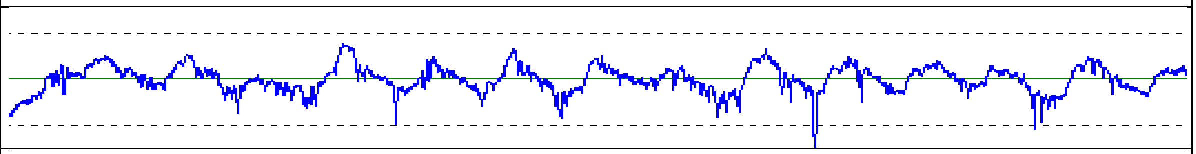
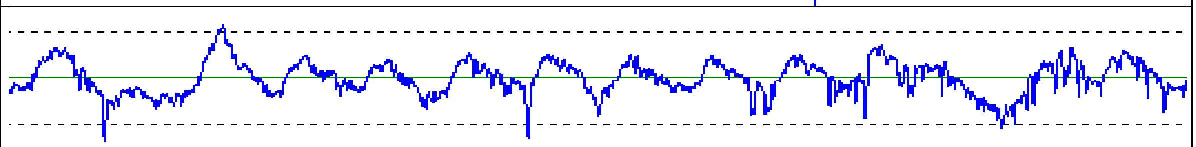
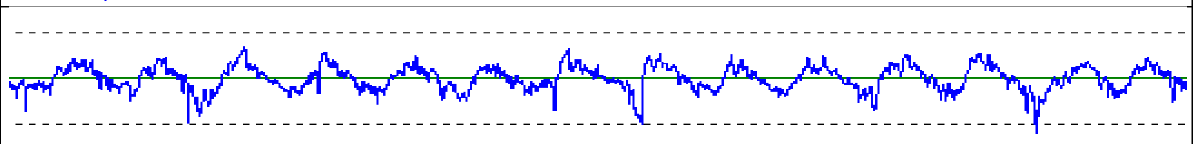
Operator C – 19/4 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

	Workpiece R1 – 10% oil concentration (R0.3/W2)
i	
j	
k	
l	
	Workpiece R2 – 10% oil concentration (R0.3/W2)
i	
j	
k	
l	
	Workpiece R3 – 10% oil concentration (R0.3/W2)
i	
j	
k	
l	

Operator C – 19/4 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

	Workpiece P1 – mineral oil (P0.3/M)
i	
j	
k	
l	
	Workpiece P2 – mineral oil (P0.3/M)
i	
j	
k	
l	
	Workpiece P3 – mineral oil (P0.3/M)
i	
j	
k	
l	

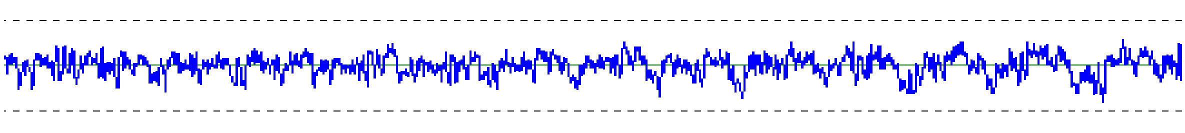
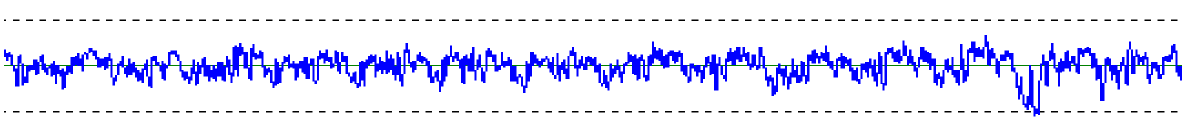
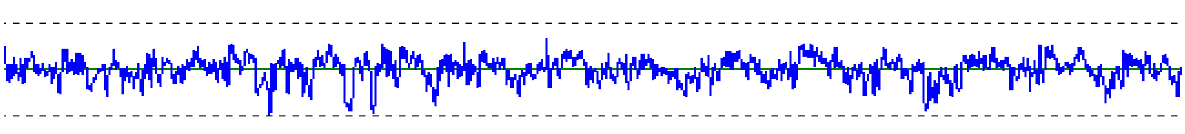
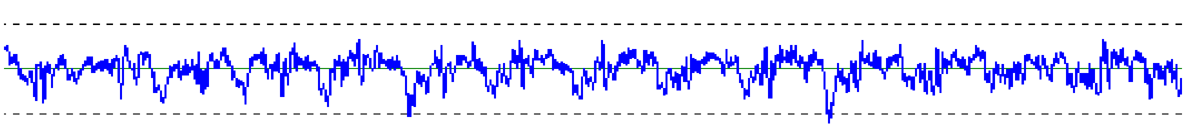
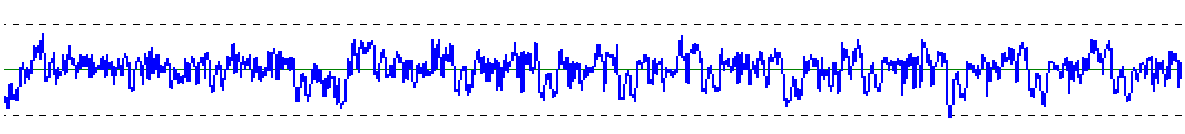
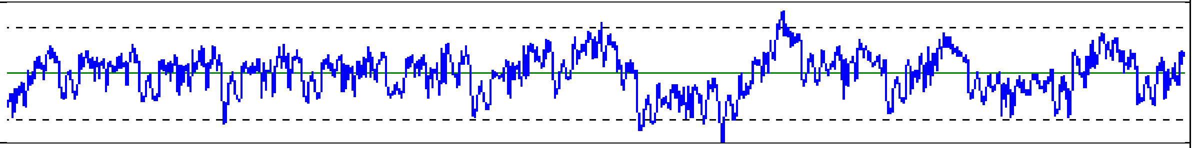
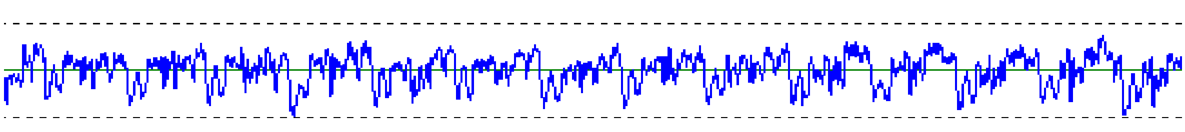
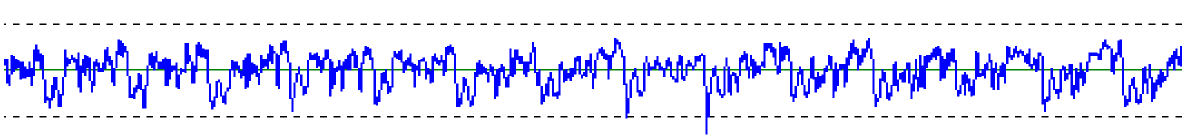
Operator C – 19/4 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

	Workpiece R1 – mineral oil (R0.3/M)
i	
j	
k	
l	
	Workpiece R2 – mineral oil (R0.3/M)
i	
j	
k	
l	
	Workpiece R3 – mineral oil (R0.3/M)
i	
j	
k	
l	

Appendix B4: Surface roughness measurement

Operator A: 26/4-2010

Operator A – 26/4 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

	Workpiece P1 – 1% oil concentration (P0.3/W1)
i	
j	
k	
l	
	Workpiece P2 – 1% oil concentration (P0.3/W1)
i	
j	
k	
l	
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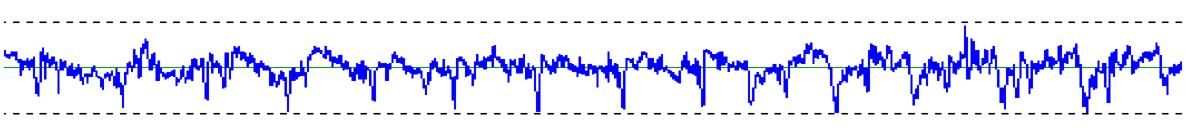
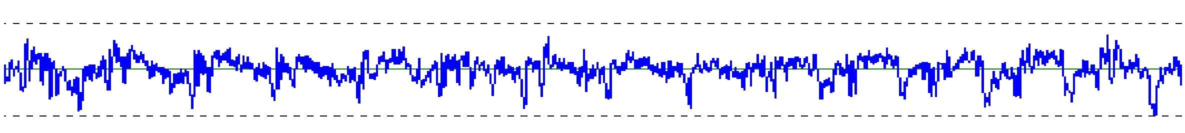
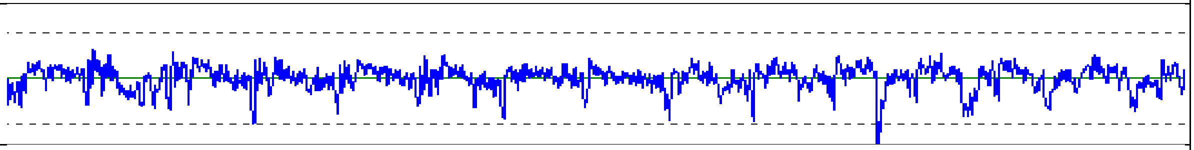
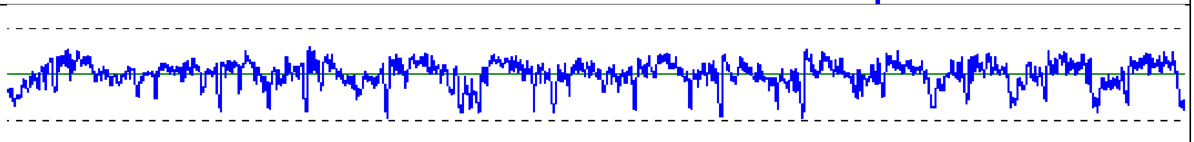
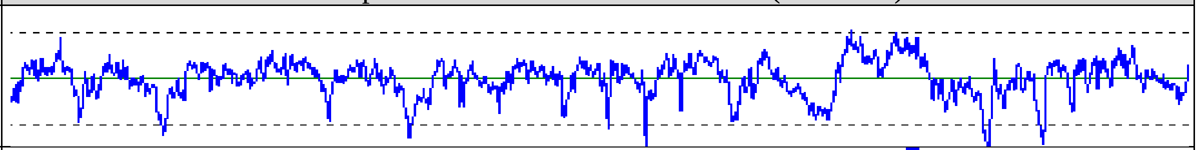
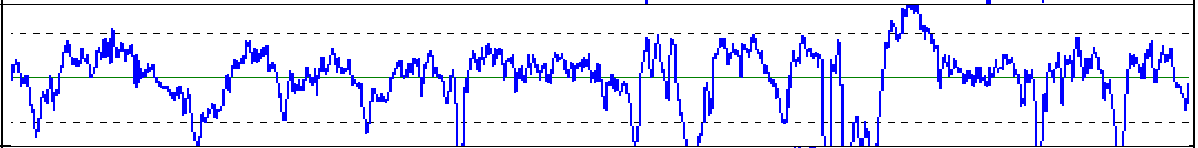
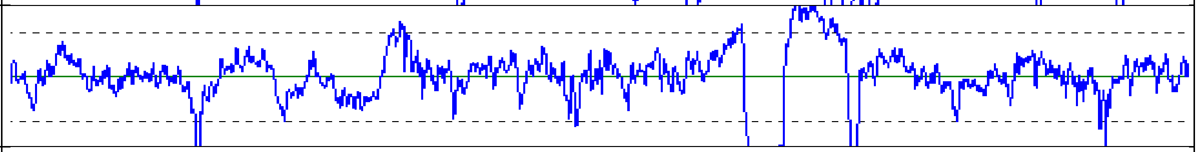
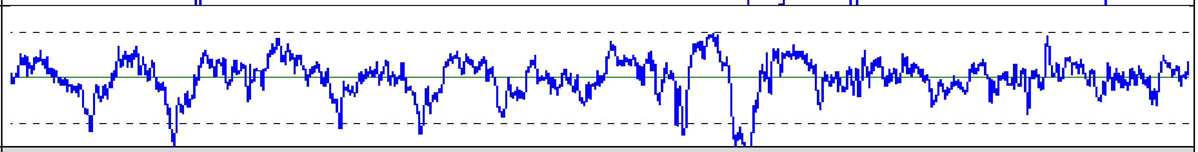
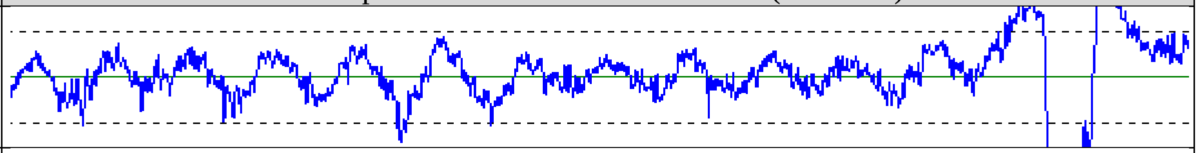
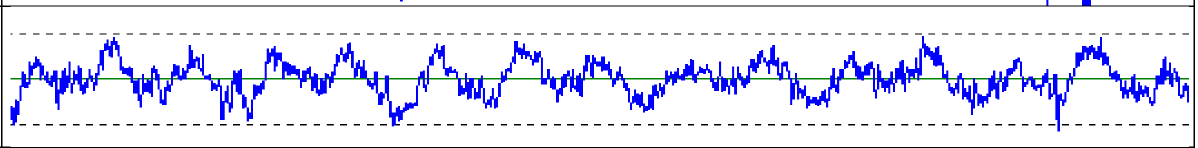
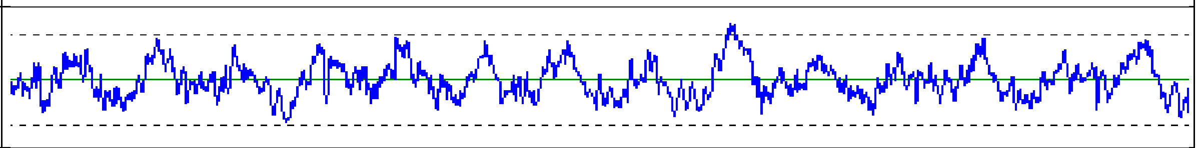
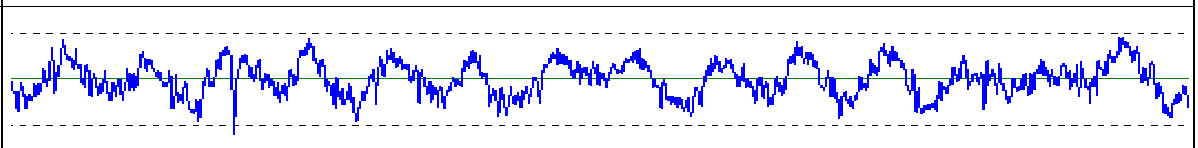
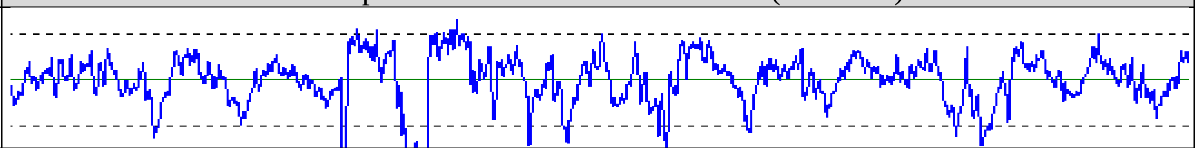
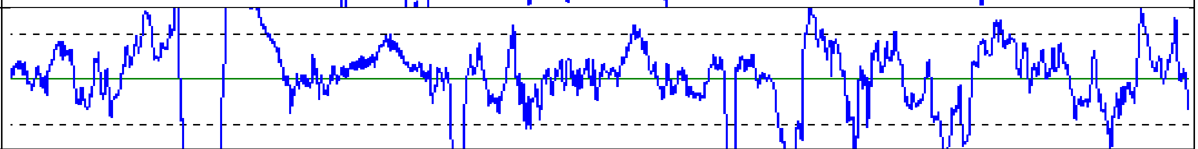
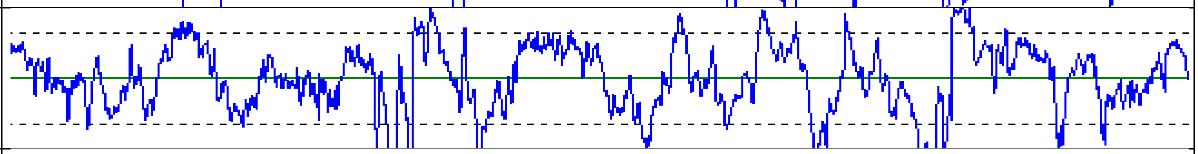
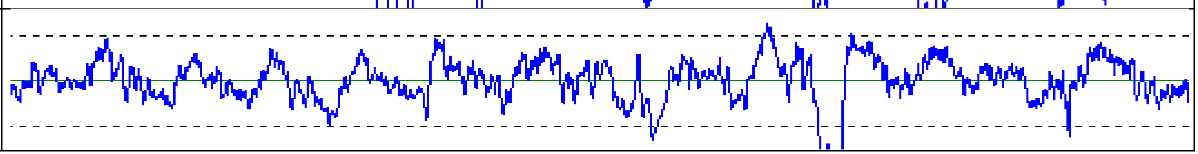
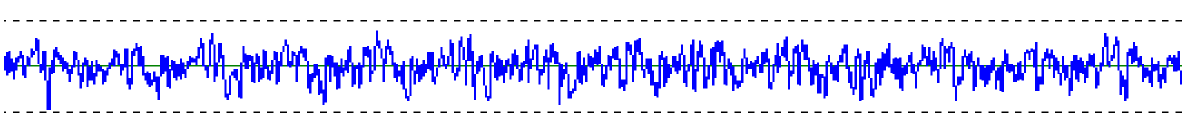
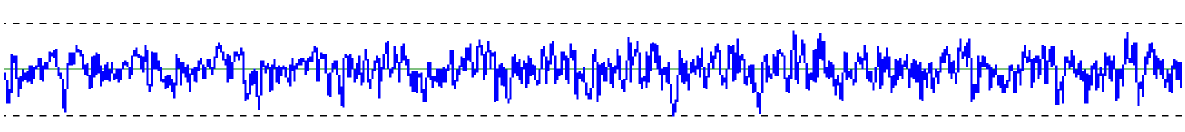
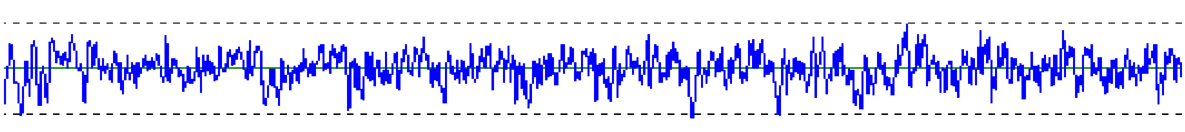
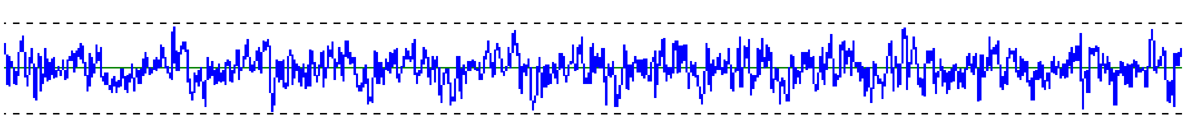
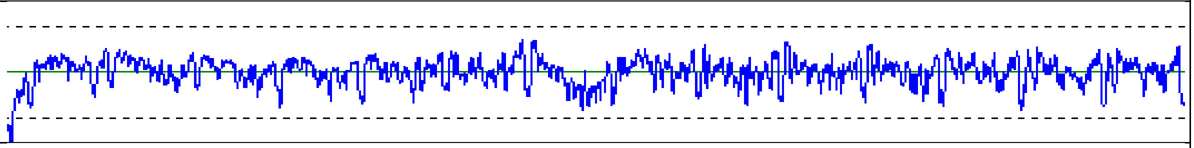
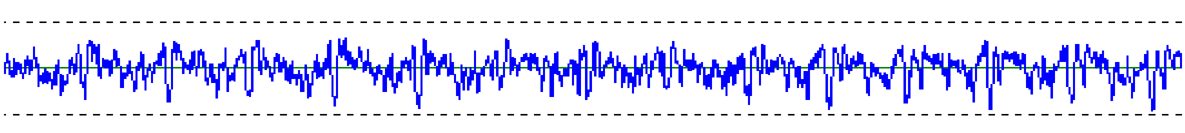
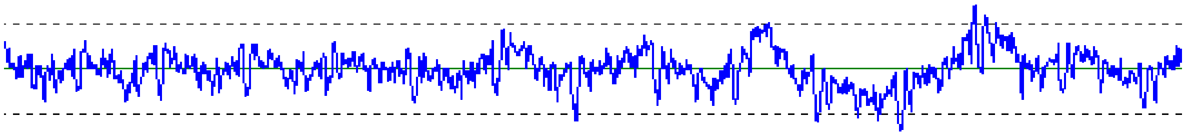
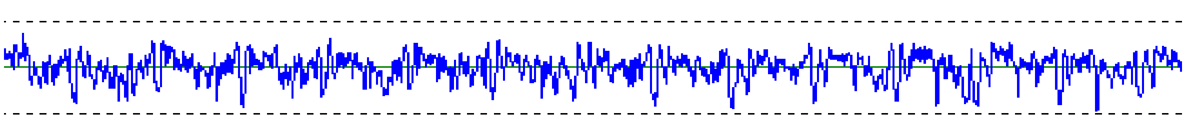
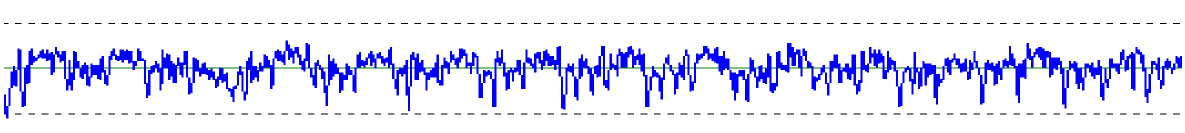
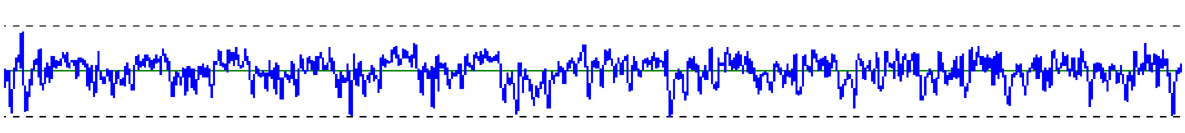
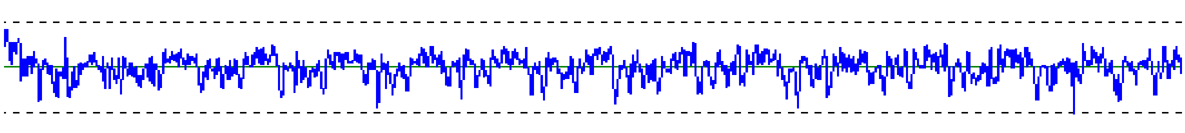
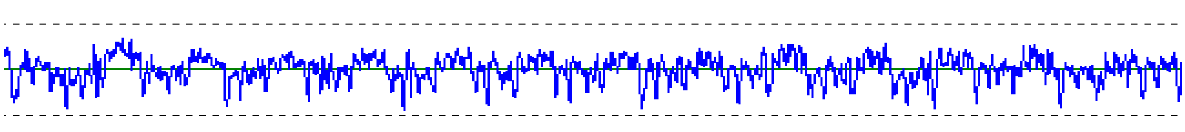
i	
j	
k	
l	

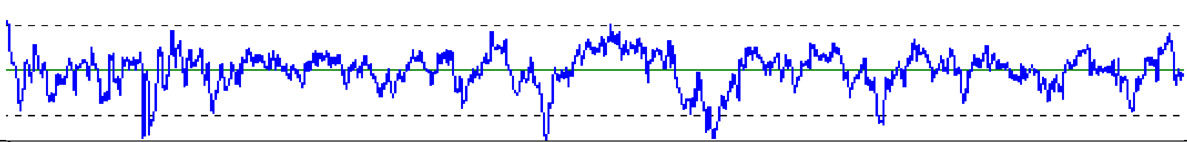
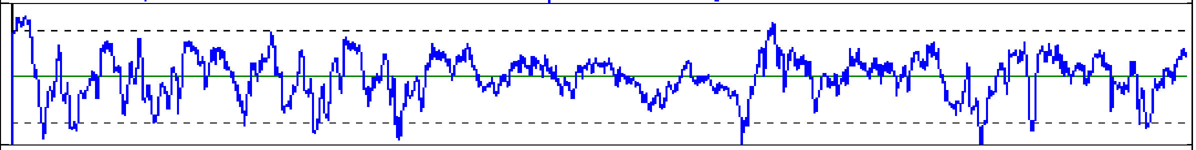
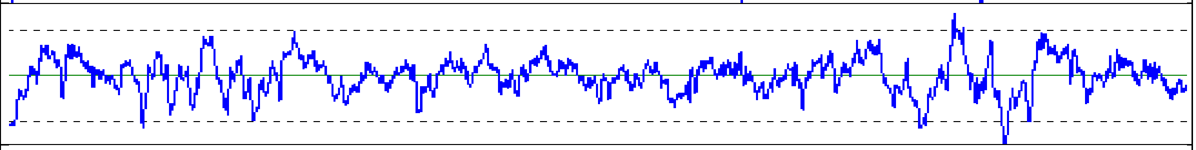
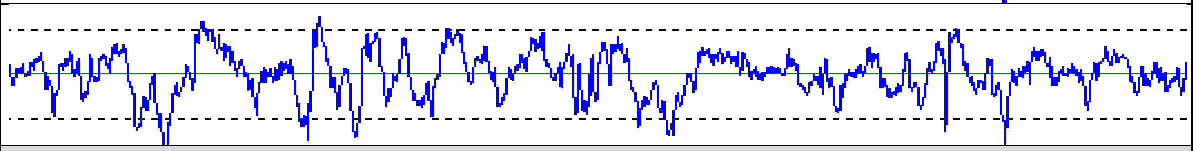
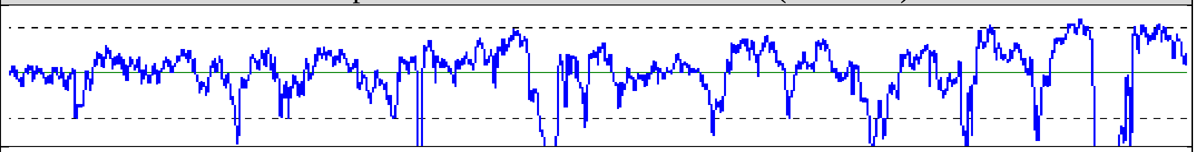
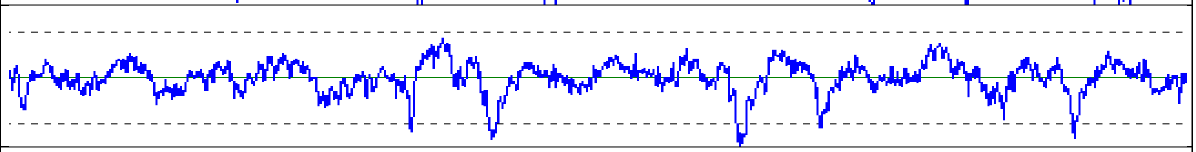
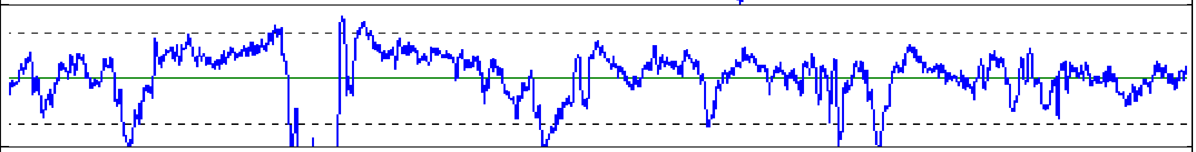
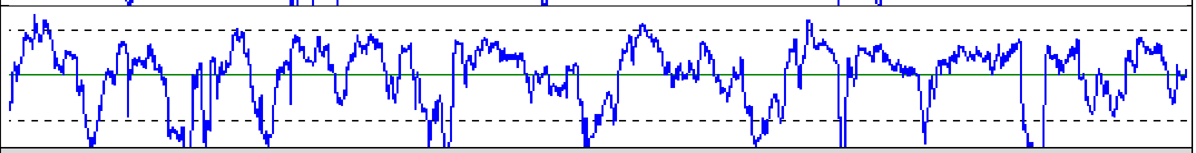
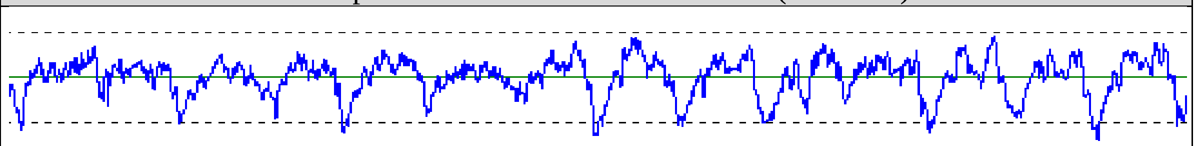
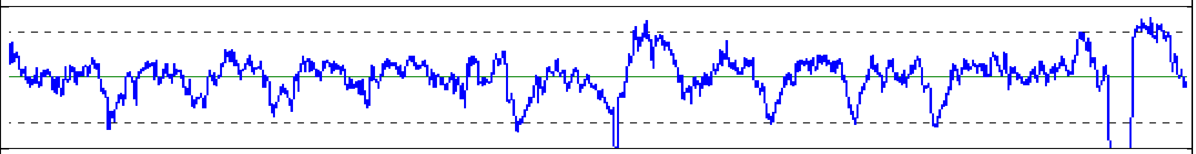
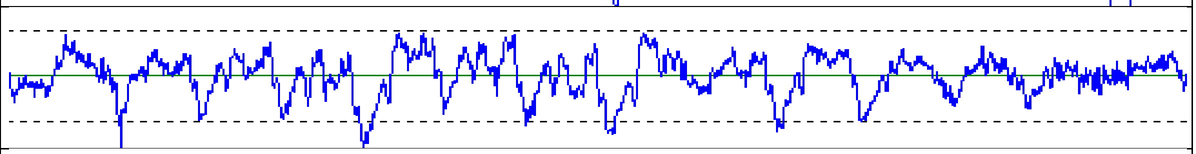
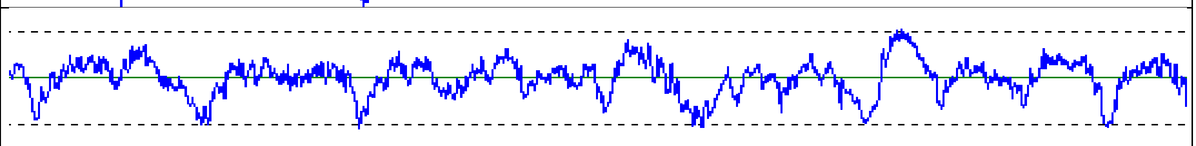
Operator A – 26/4 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

	Workpiece R1 – 1% oil concentration (R0.3/W1)
i	
j	
k	
l	
	Workpiece R2 – 1% oil concentration (R0.3/W1)
i	
j	
k	
l	
	Workpiece R3 – 1% oil concentration (R0.3/W1)
i	
j	
k	
l	

Operator A – 26/4 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

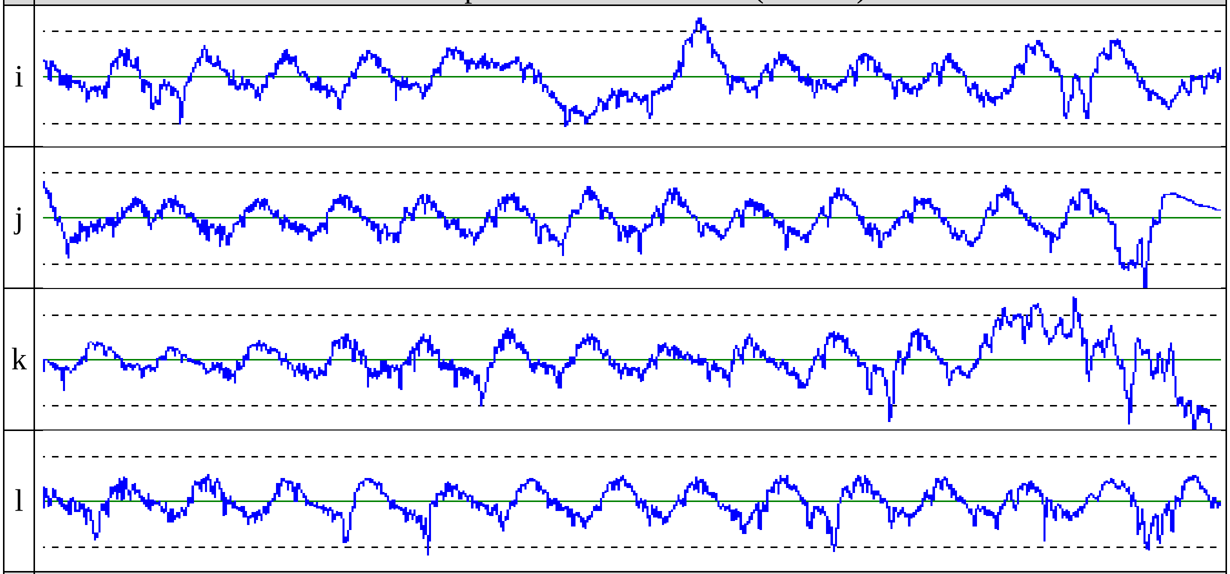
	Workpiece P1 – 10% oil concentration (P0.3/W2)
i	
j	
k	
l	
	Workpiece P2 – 10% oil concentration (P0.3/W2)
i	
j	
k	
l	
	Workpiece P3 – 10% oil concentration (P0.3/W2)
i	
j	
k	
l	

Operator A – 26/4 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

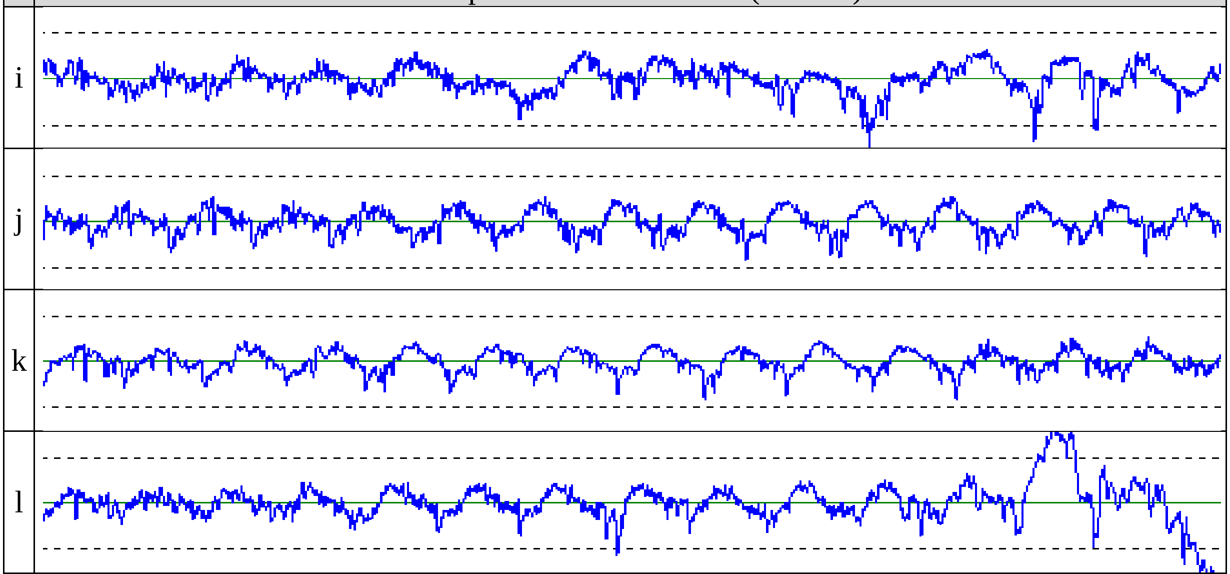
	Workpiece R1 – 10% oil concentration (R0.3/W2)
i	
j	
k	
l	
	Workpiece R2 – 10% oil concentration (R0.3/W2)
i	
j	
k	
l	
	Workpiece R3 – 10% oil concentration (R0.3/W2)
i	
j	
k	
l	

Operator A – 26/4 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

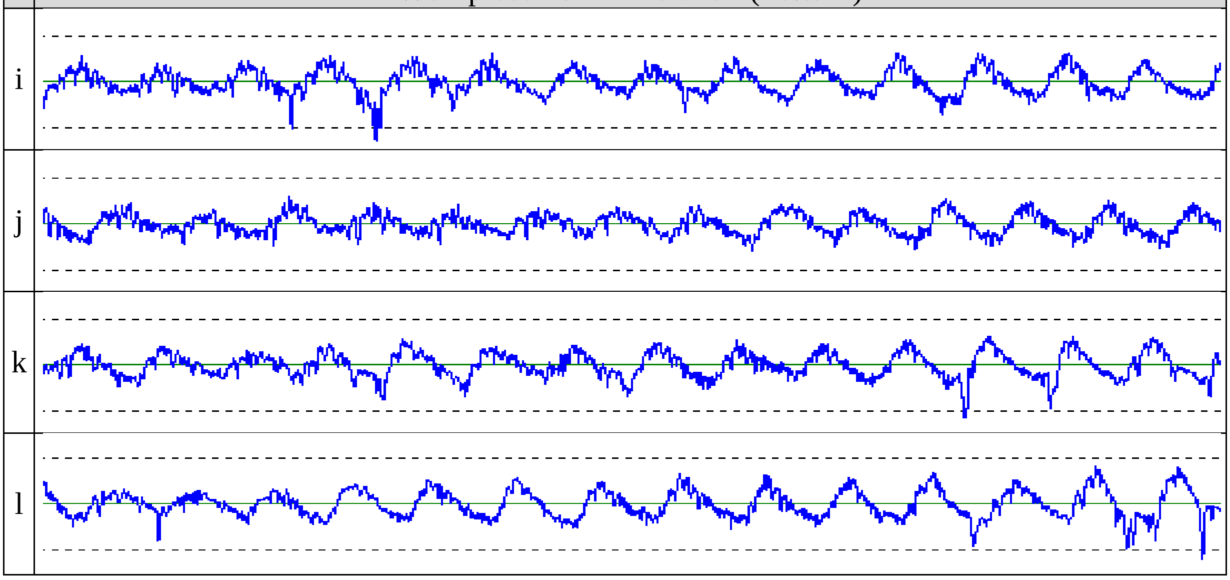
Workpiece P1 – mineral oil (P0.3/M)



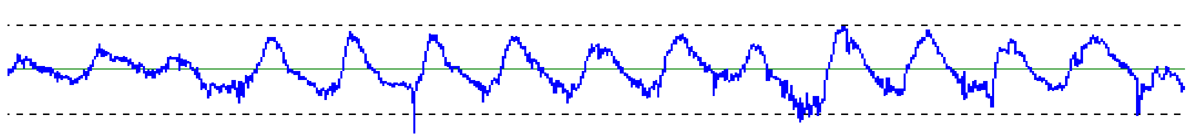
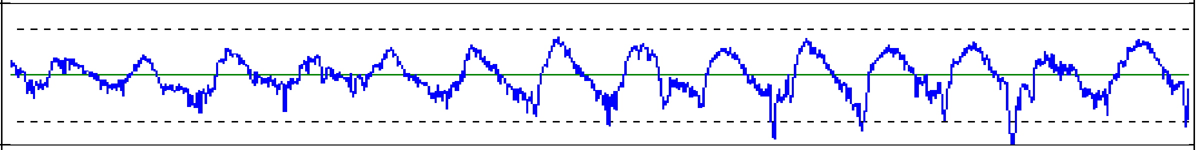
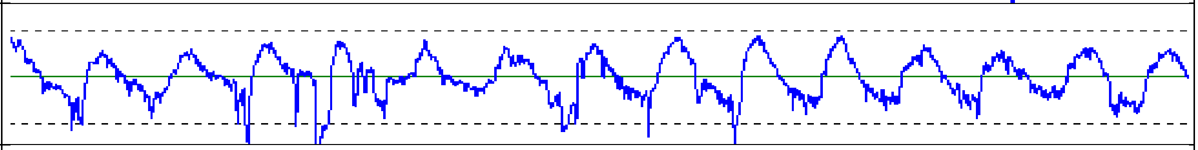
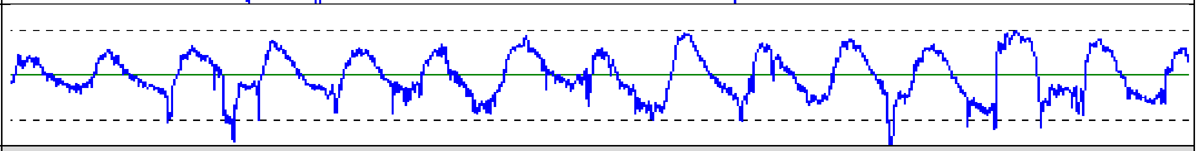
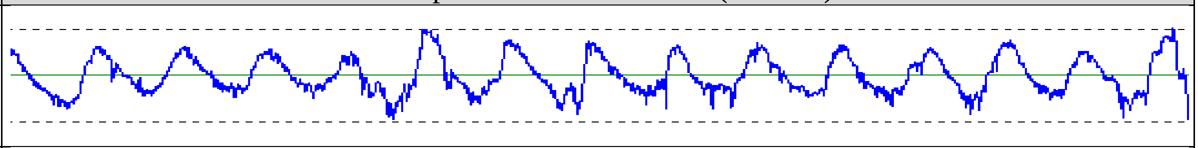
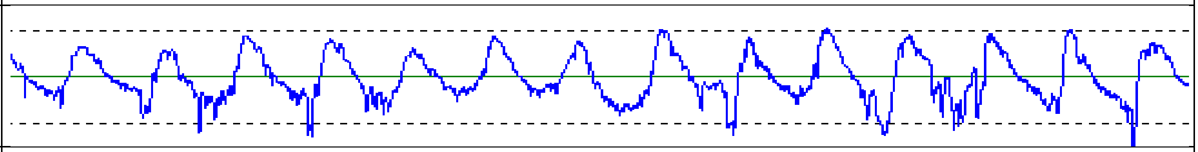
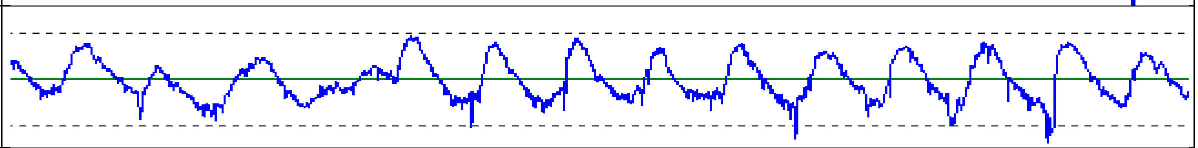
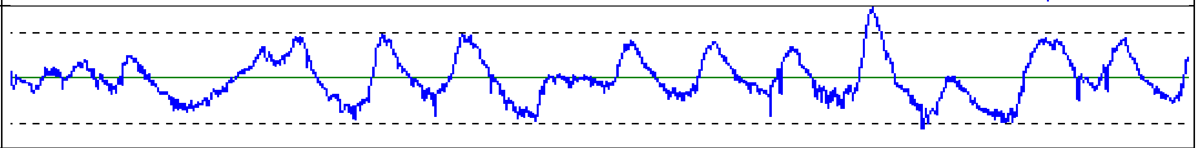
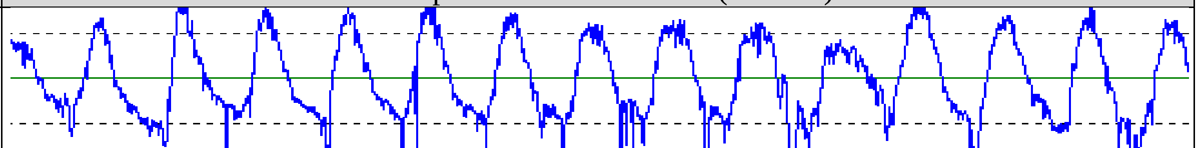
Workpiece P2 – mineral oil (P0.3/M)



Workpiece P3 – mineral oil (P0.3/M)



Operator A – 26/4 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

	Workpiece R1 – mineral oil (R0.3/M)
i	
j	
k	
l	
	Workpiece R2 – mineral oil (R0.3/M)
i	
j	
k	
l	
	Workpiece R3 – mineral oil (R0.3/M)
i	
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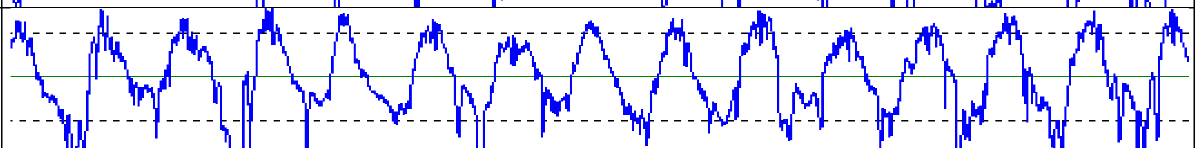
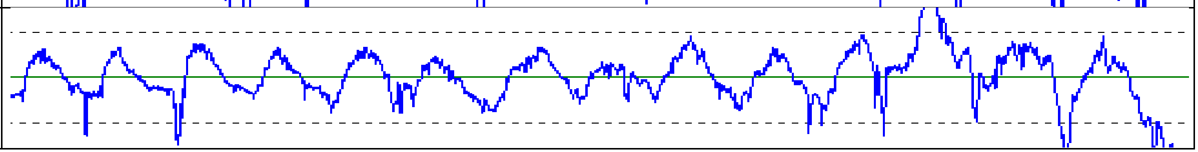
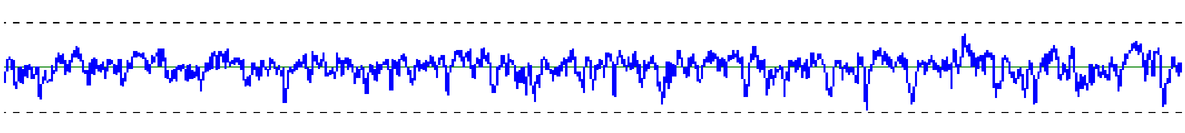
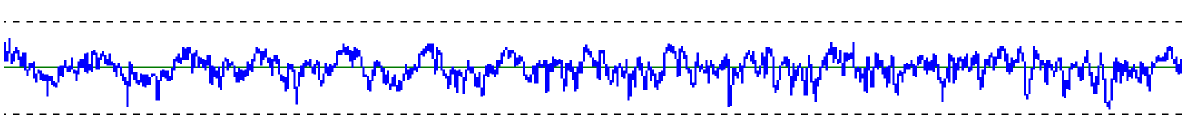
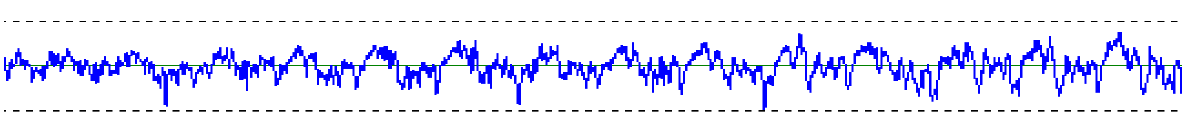
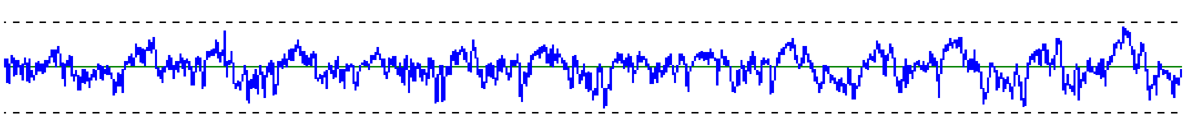
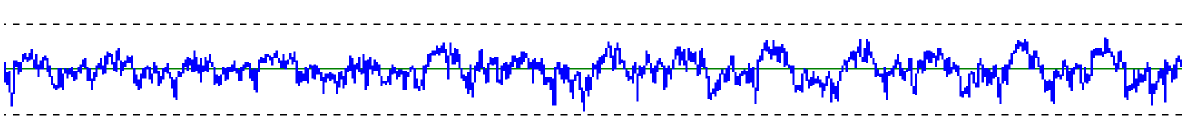
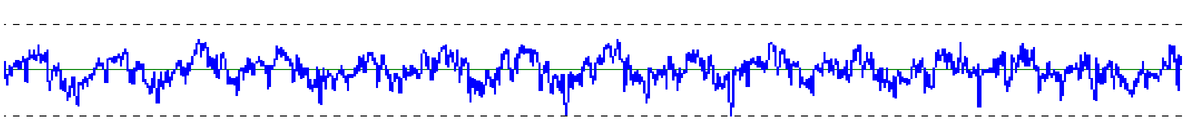
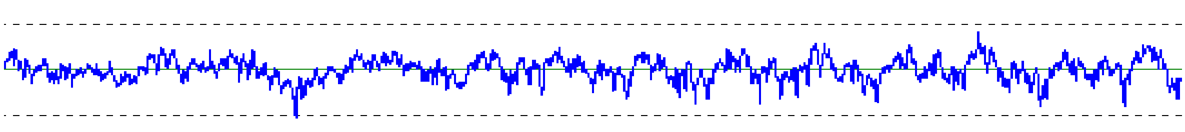
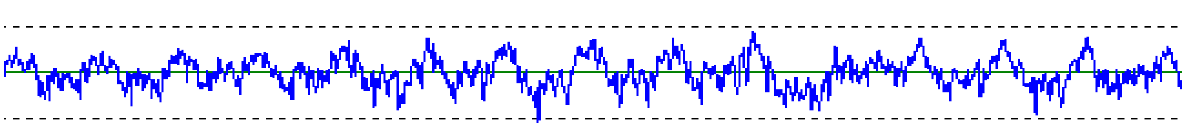
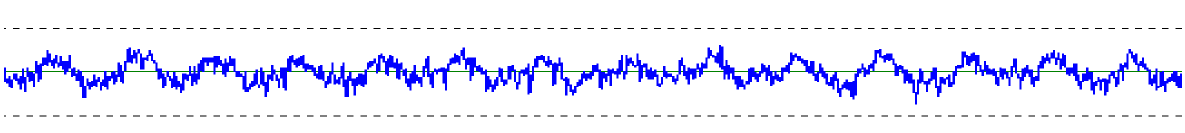
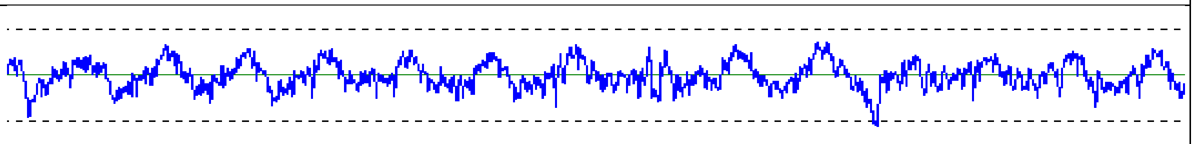
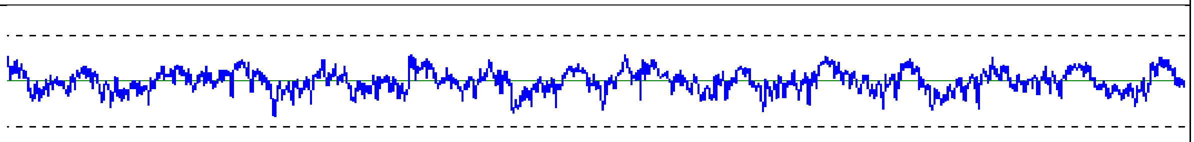
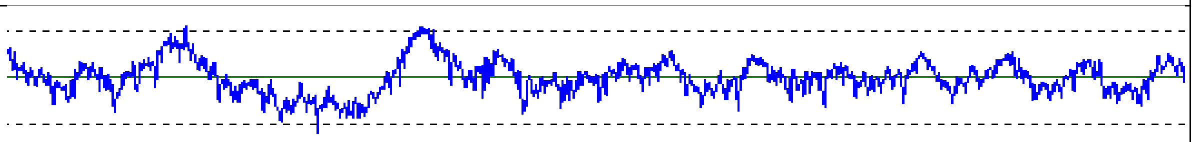
k	
l	

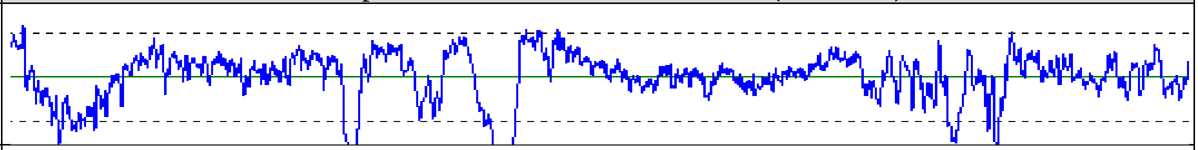
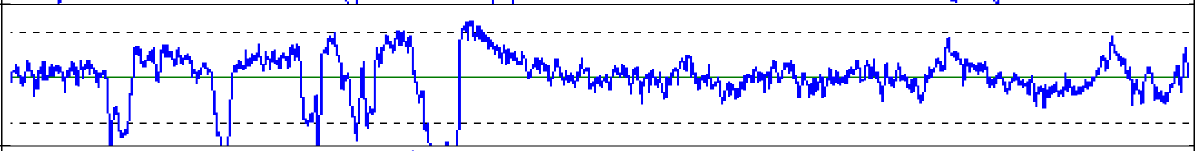
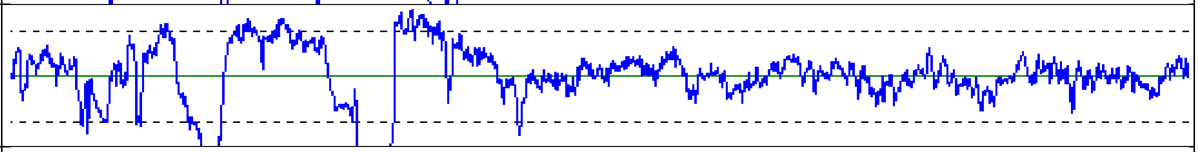
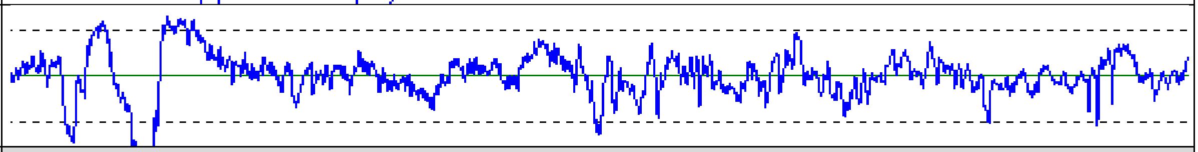
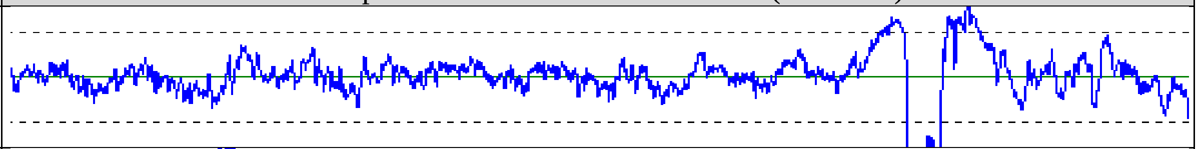
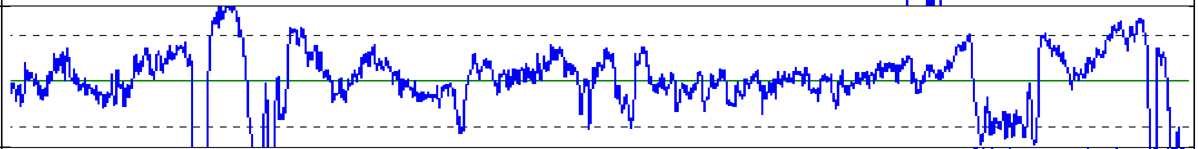
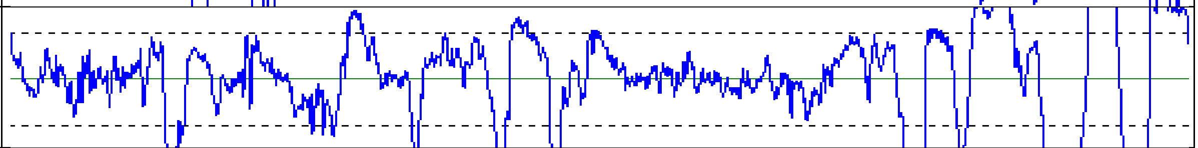
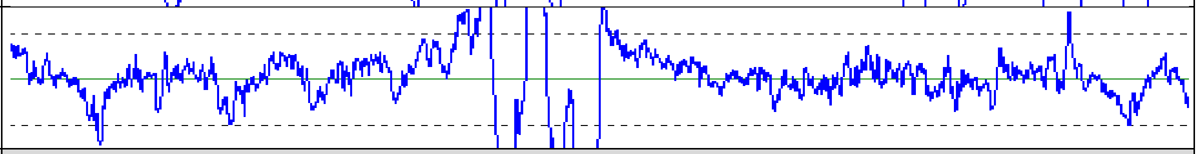
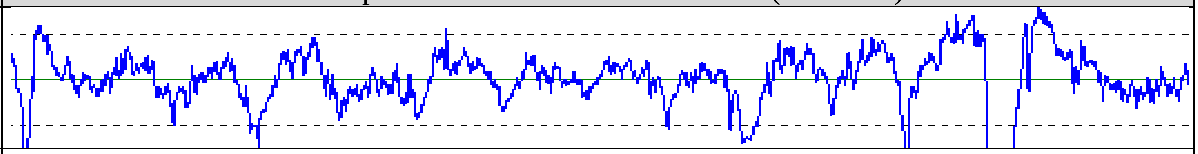
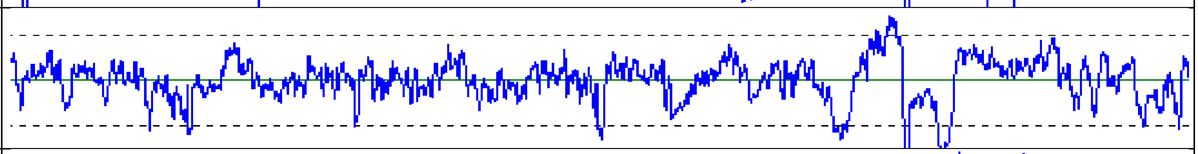
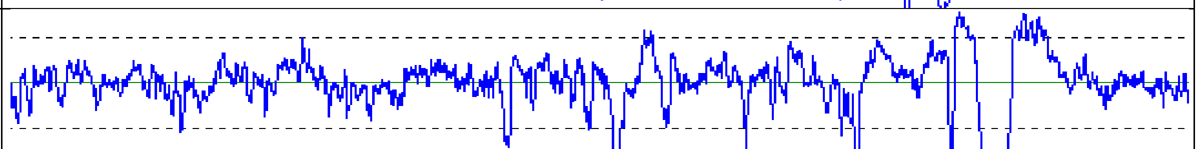
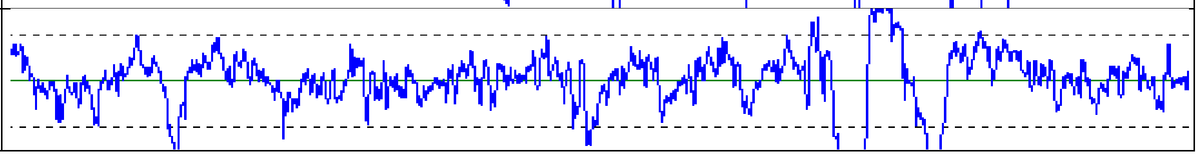
Appendix B5: Surface roughness measurement

Operator D: 3/5-2010

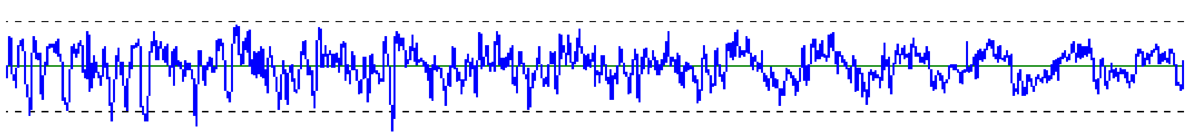
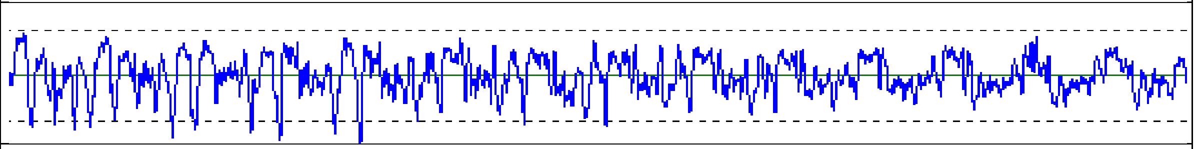
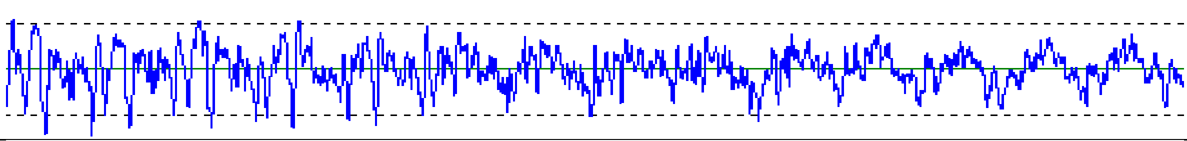
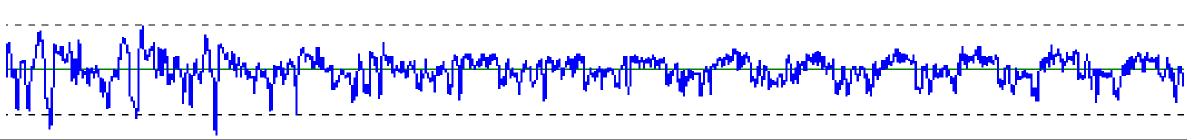
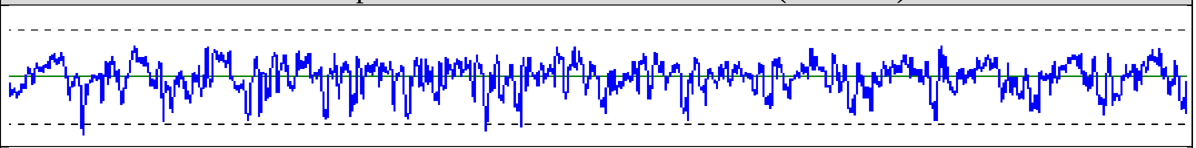
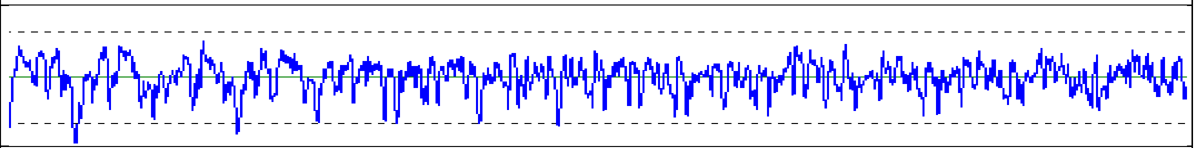
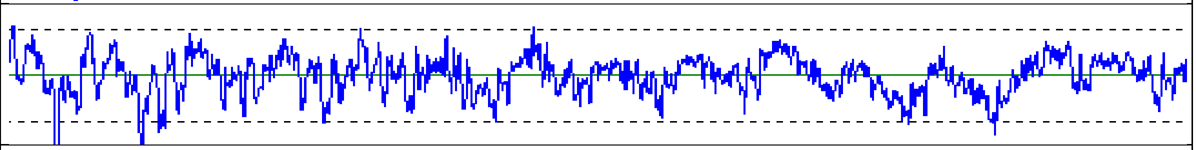
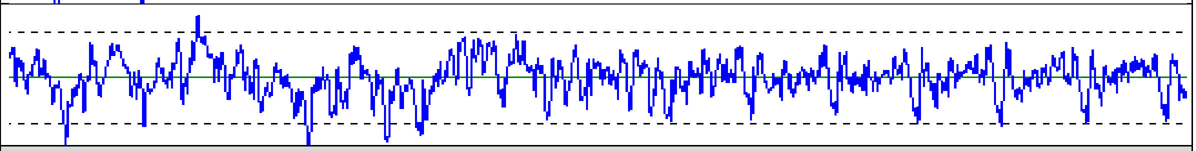
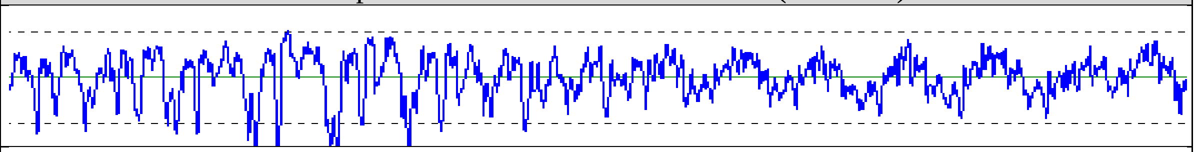
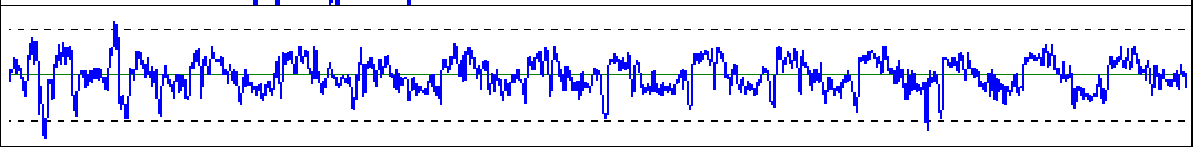
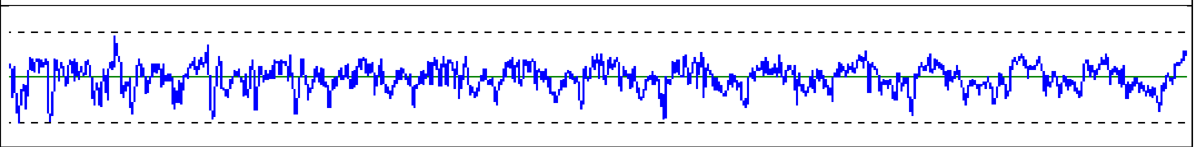
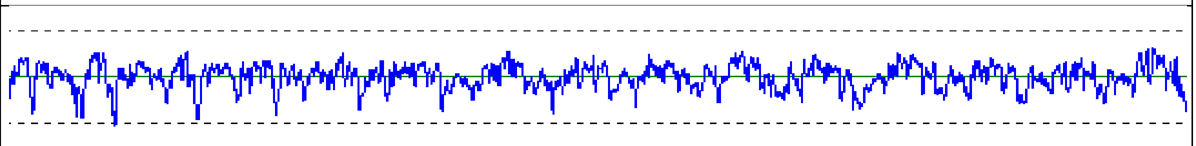
Operator D – 3/5 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

	Workpiece P1 – 1% oil concentration (P0.3/W1)
i	
j	
k	
l	
	Workpiece P2 – 1% oil concentration (P0.3/W1)
i	
j	
k	
l	
	Workpiece P3 – 1% oil concentration (P0.3/W1)
i	
j	
k	
l	

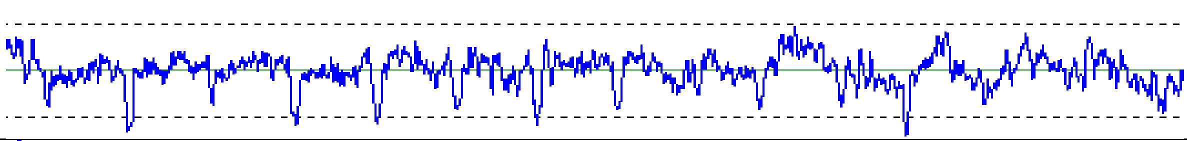
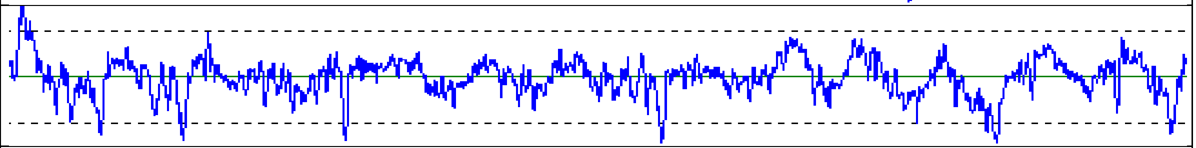
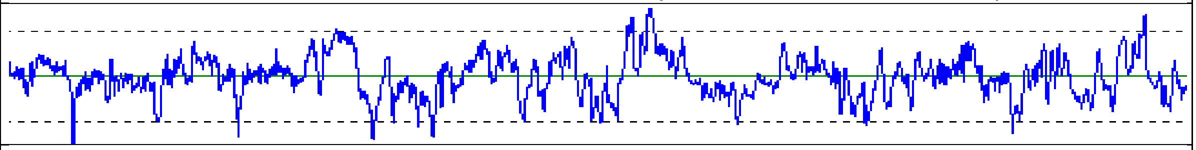
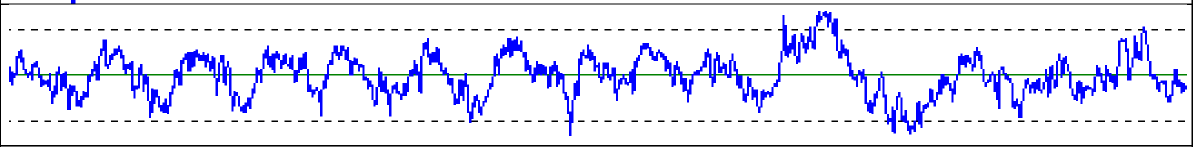
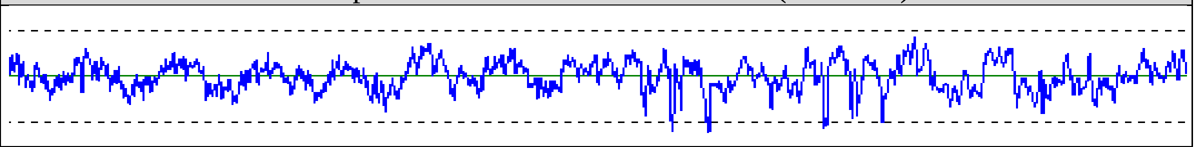
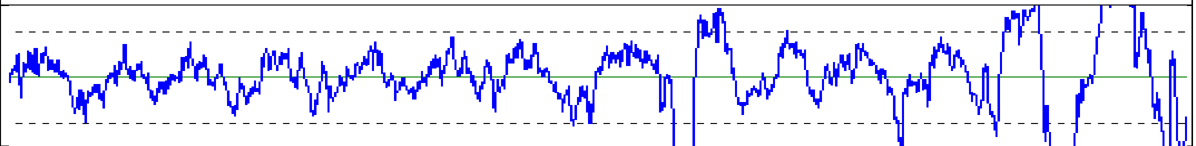
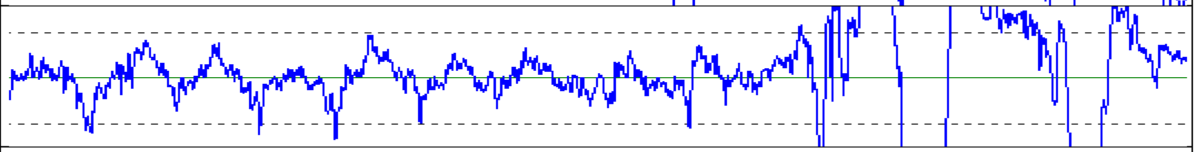
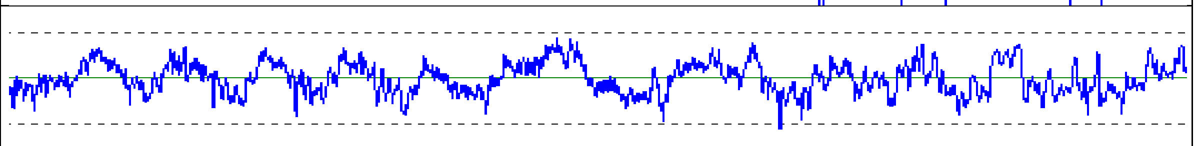
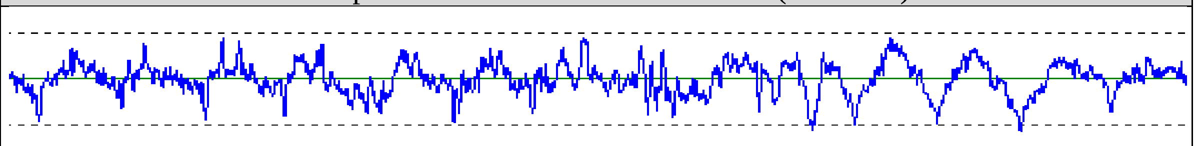
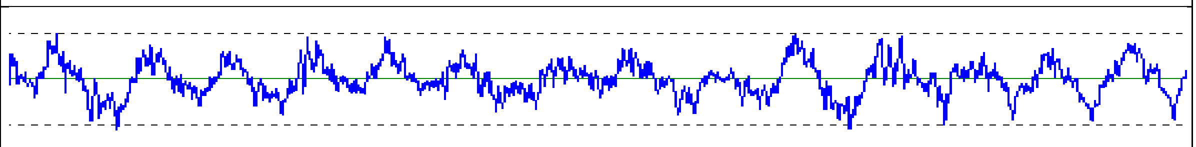
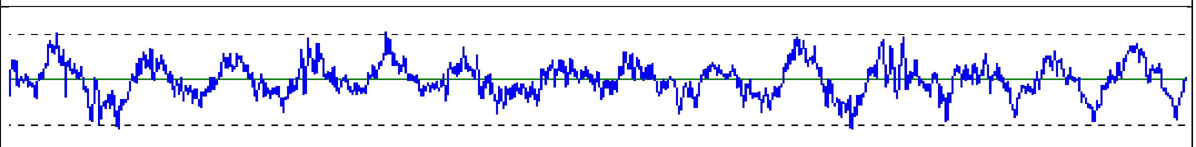
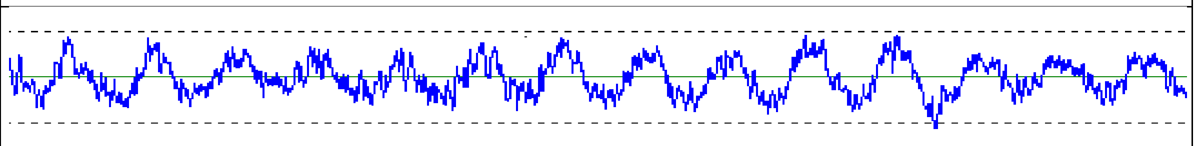
Operator D – 3/5 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

	Workpiece R1 – 1% oil concentration (R0.3/W1)
i	
j	
k	
l	
	Workpiece R2 – 1% oil concentration (R0.3/W1)
i	
j	
k	
l	
	Workpiece R3 – 1% oil concentration (R0.3/W1)
i	
j	
k	
l	

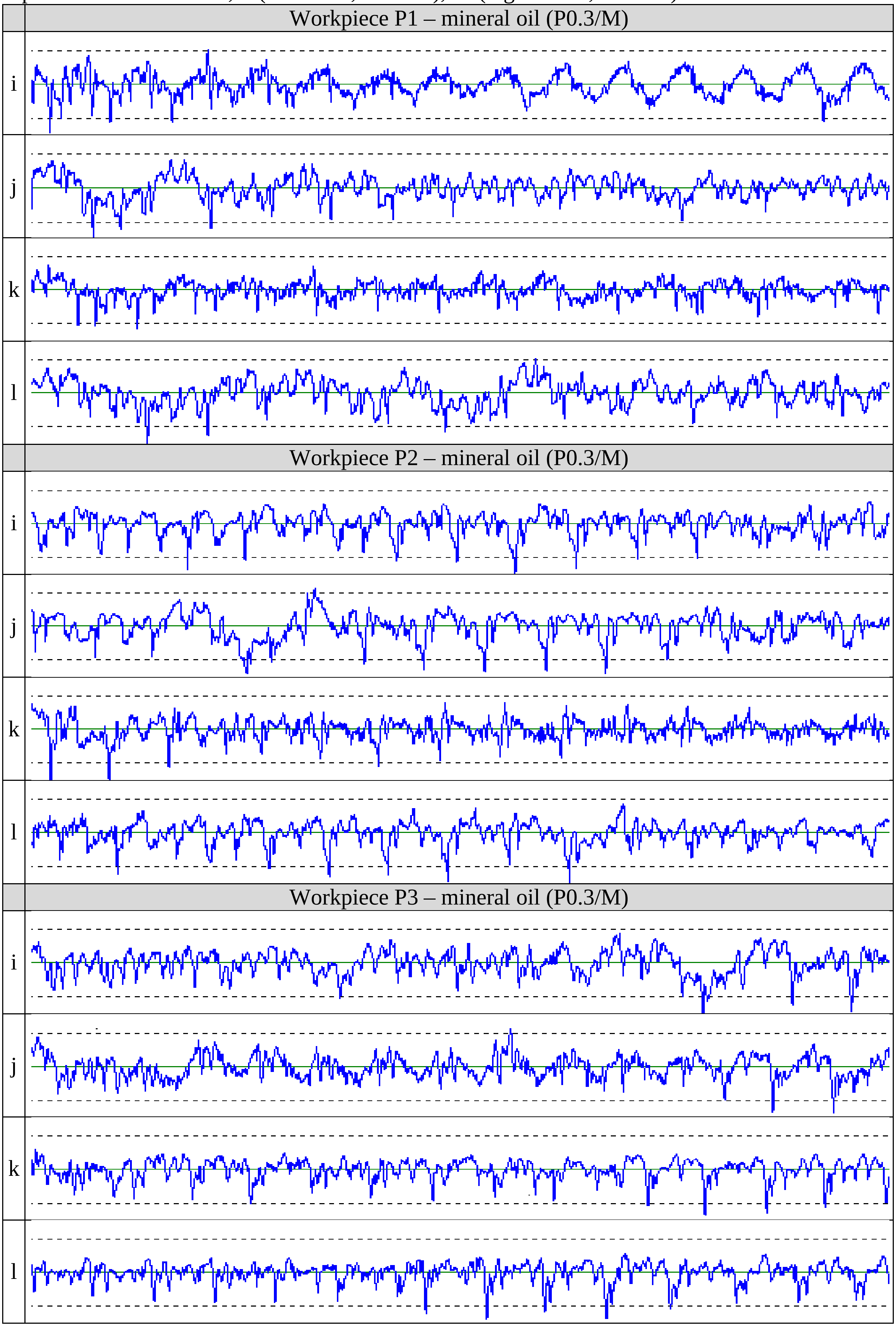
Operator D – 3/5 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

	Workpiece P1 – 10% oil concentration (P0.3/W2)
i	
j	
k	
l	
	Workpiece P2 – 10% oil concentration (P0.3/W2)
i	
j	
k	
l	
	Workpiece P3 – 10% oil concentration (P0.3/W2)
i	
j	
k	
l	

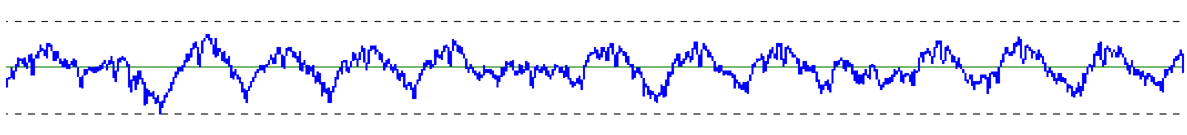
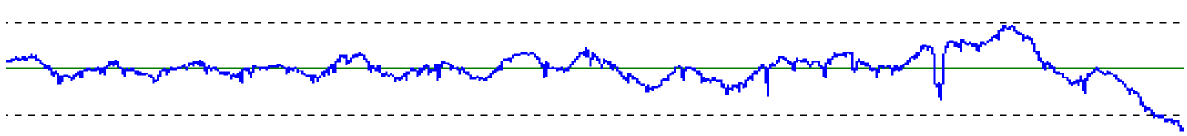
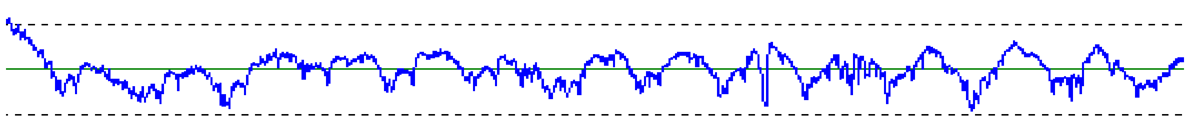
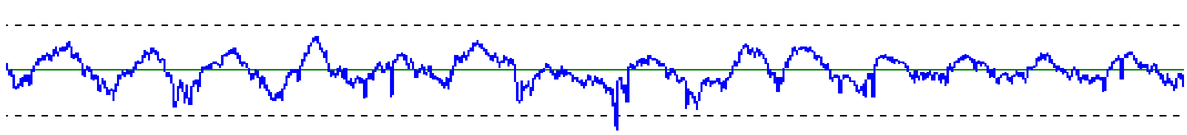
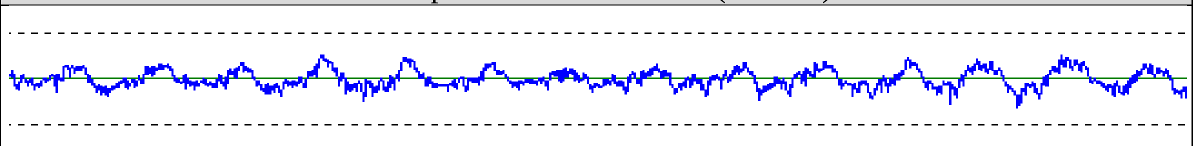
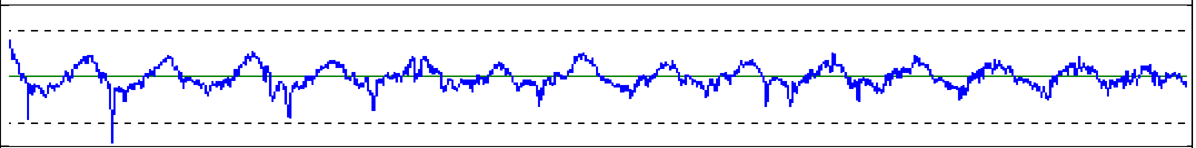
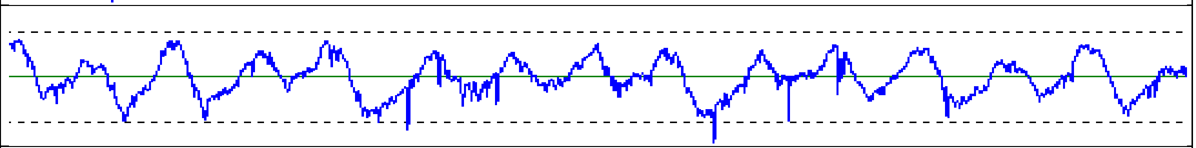
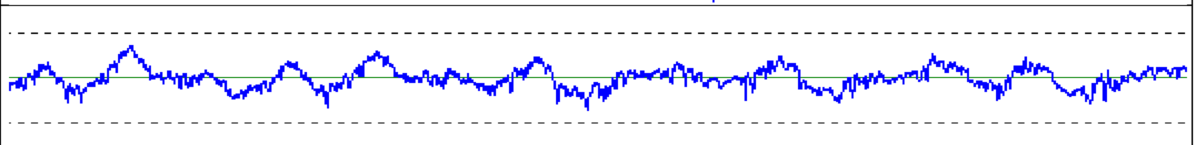
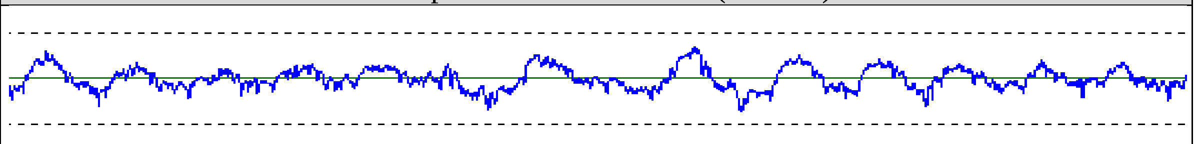
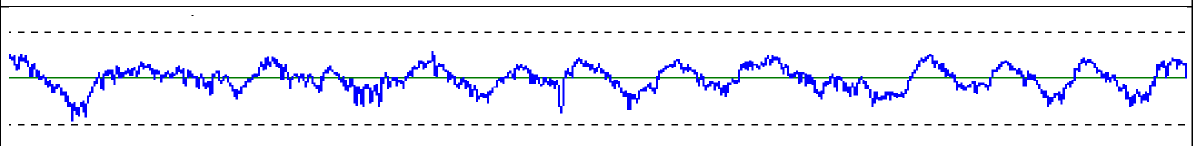
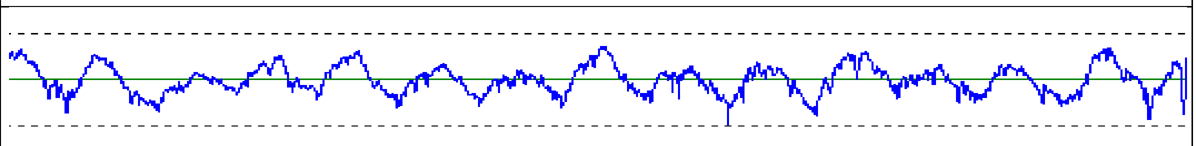
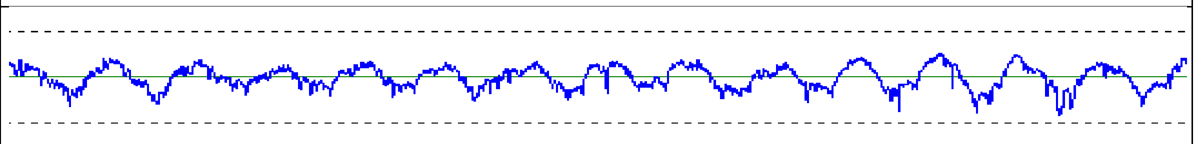
Operator D – 3/5 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

	Workpiece R1 – 10% oil concentration (R0.3/W2)
i	
j	
k	
l	
	Workpiece R2 – 10% oil concentration (R0.3/W2)
i	
j	
k	
l	
	Workpiece R3 – 10% oil concentration (R0.3/W2)
i	
j	
k	
l	

Operator D – 3/5 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)



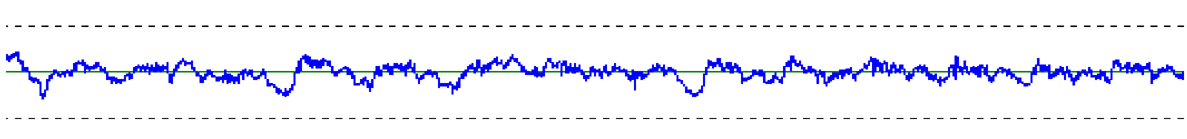
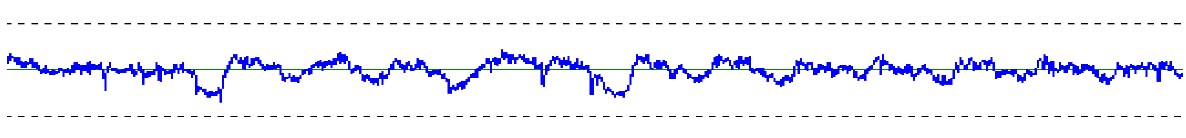
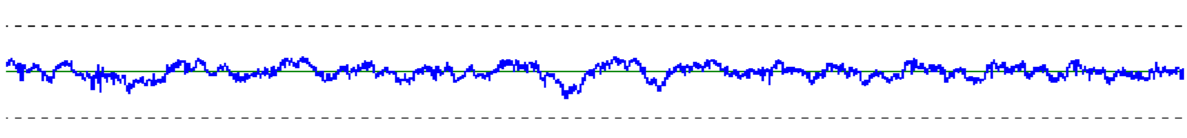
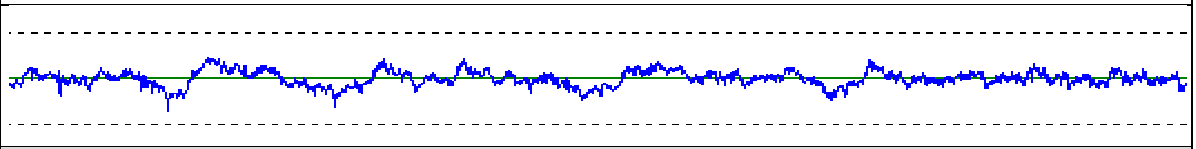
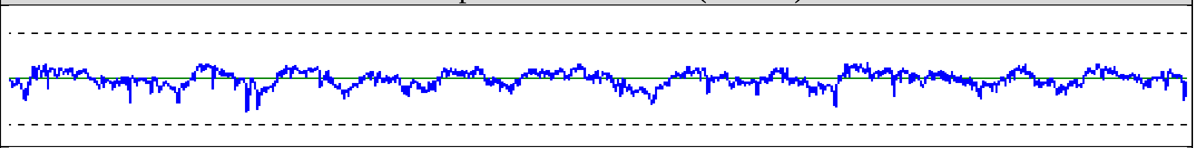
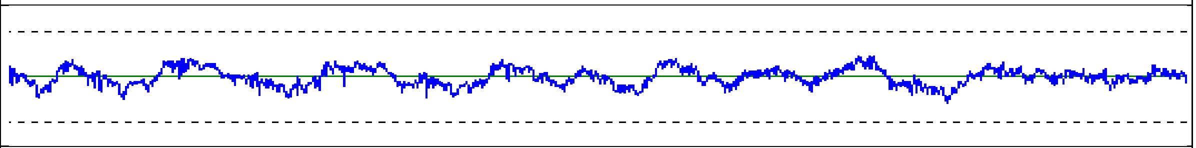
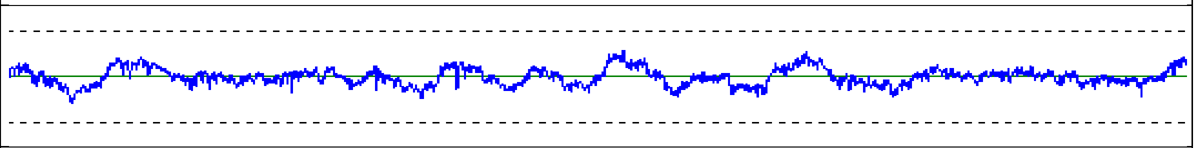
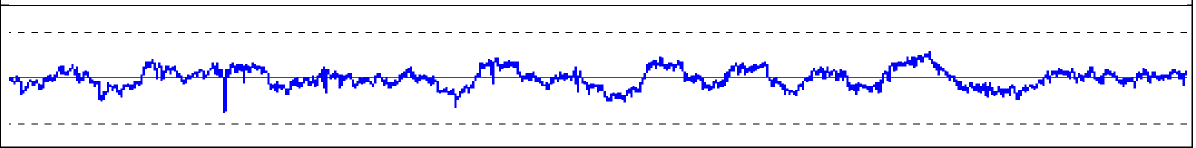
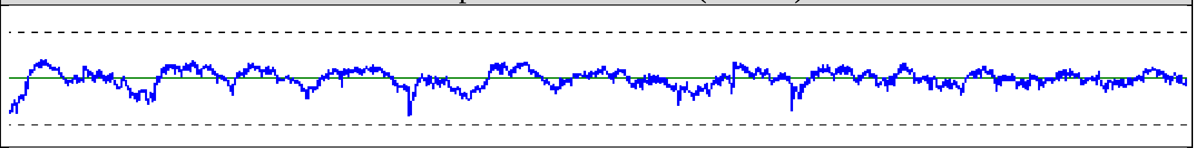
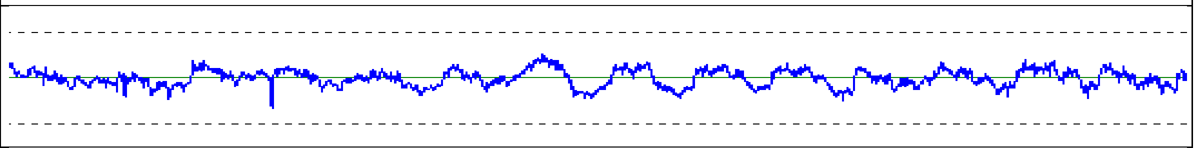
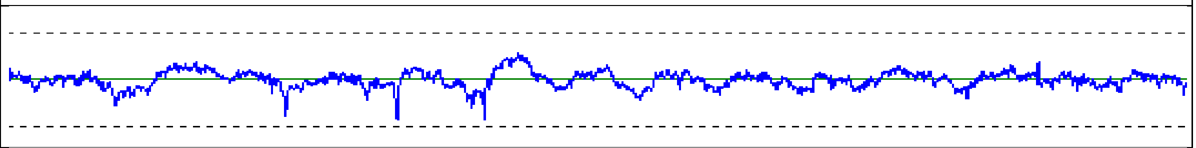
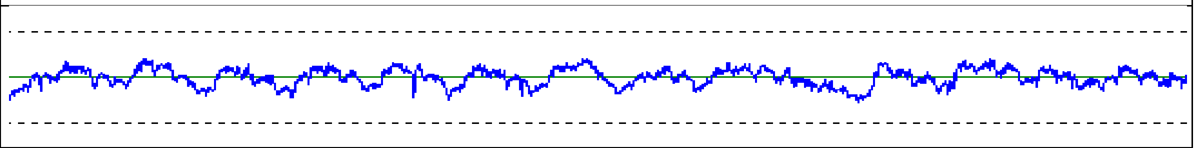
Operator D – 3/5 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

	Workpiece R1 – mineral oil (R0.3/M)
i	
j	
k	
l	
	Workpiece R2 – mineral oil (R0.3/M)
i	
j	
k	
l	
	Workpiece R3 – mineral oil (R0.3/M)
i	
j	
k	
l	

Appendix B6: Surface roughness measurement

Operator F: 22/6-2010

Operator F – 22/6 – 2010; P (low vc=4,5 m/min)

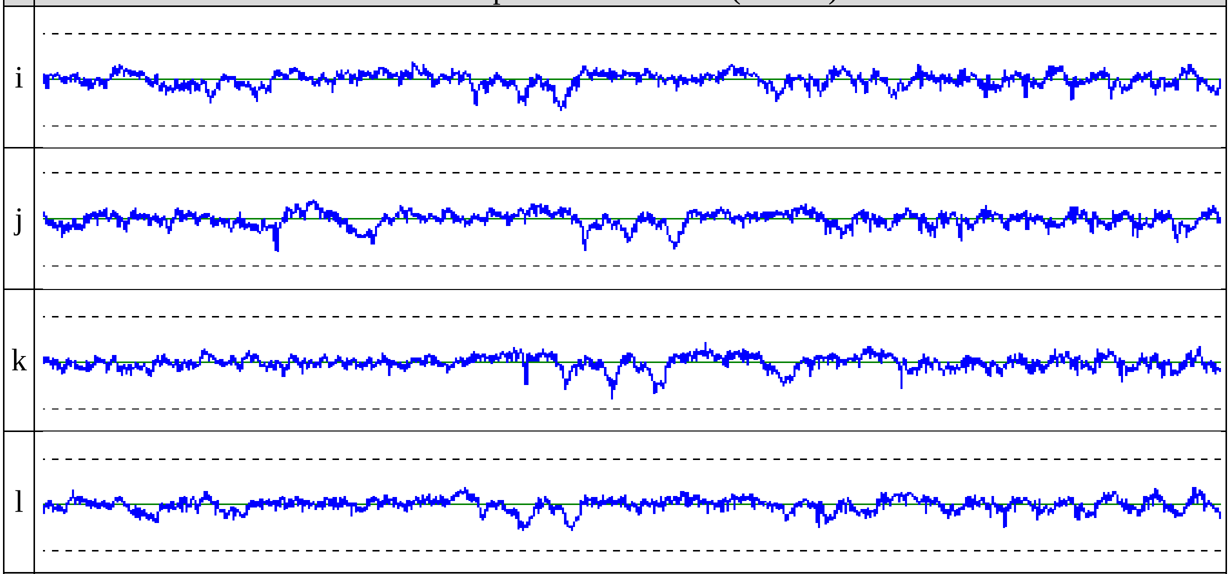
	Workpiece P1 – neat oil (P0.3/N)
i	
j	
k	
l	
	Workpiece P2 – neat oil (P0.3/N)
i	
j	
k	
l	
	Workpiece P3 – neat oil (P0.3/N)
i	
j	
k	
l	

Appendix B7: Surface roughness measurement

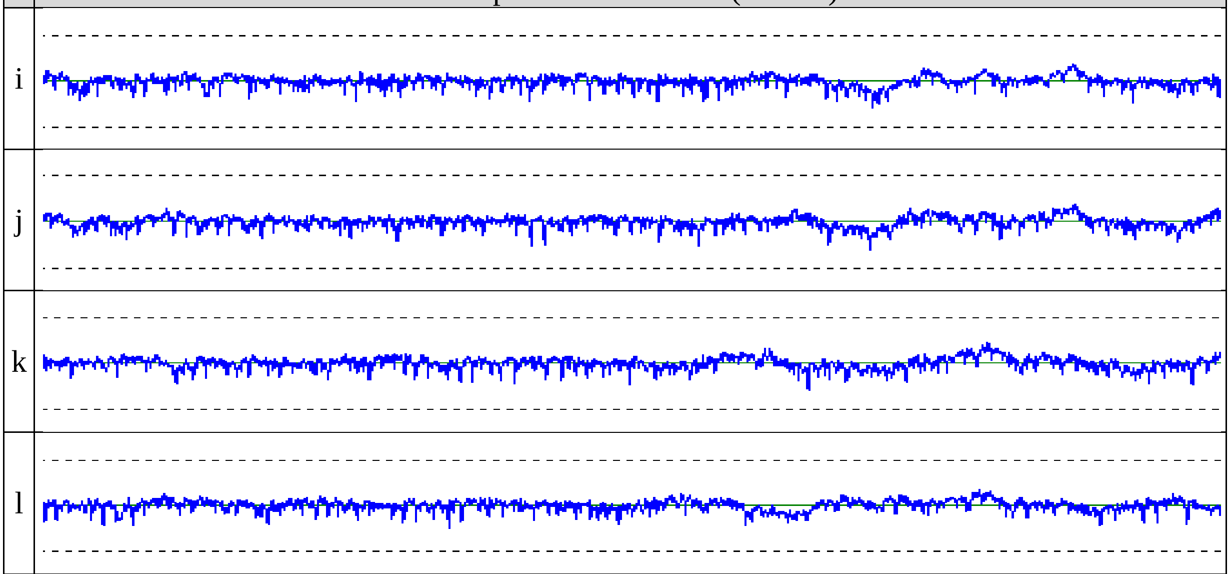
Operator G: 22/6-2010

Operator G – 22/6 – 2010; P (low vc=4,5 m/min)

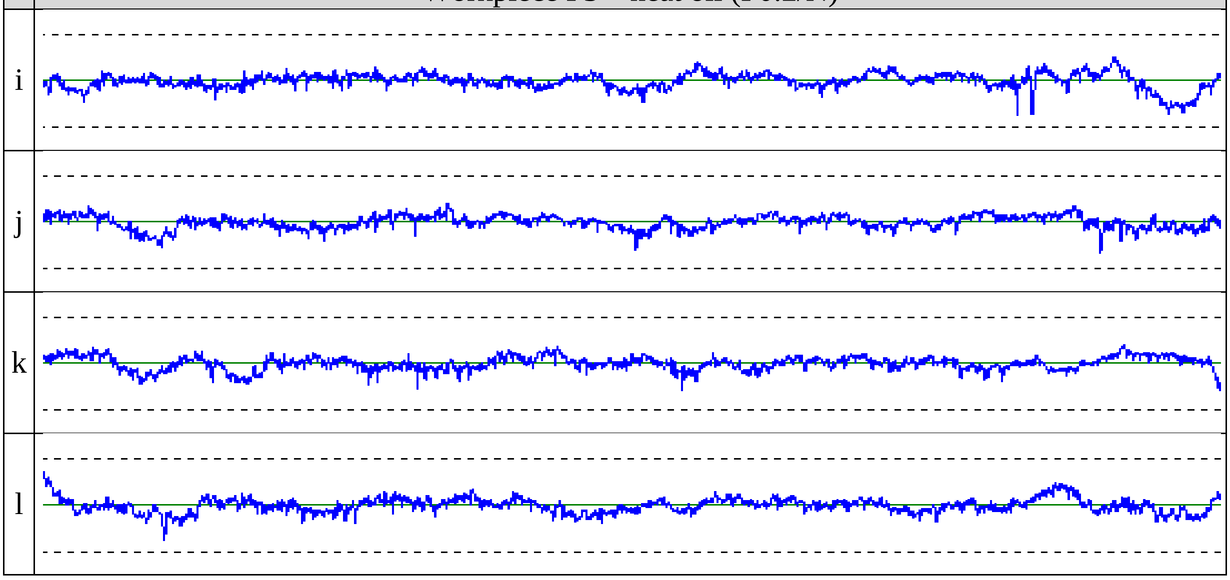
Workpiece P1 – neat oil (P0.2/N)



Workpiece P2 – neat oil (P0.2/N)



Workpiece P3 – neat oil (P0.2/N)



Appendix C

2D reference measurements

Appendix C contains profiles of 2D reference measurements which were performed by Rene Sobiecki. The two reference instruments were Form TalySurf 2 and RTH TalySurf 5-120, both from Taylor Hobson.

Table C.1: Workpieces measured using Form TalySurf 2.

Operator	Date	WP indication	Lubrication	Code
C	19.4.2010	P2	W1	P/W1
C	19.4.2010	P1	W2	P/W2
C	19.4.2010	P1	M	P/M
F	22.6.2010	P2	N	P0.3/N
G	22.6.2010	P2	N	P0.2/N

Table C.2: Workpieces measured using RTH TalySurf 5-120.

Operator	Date	WP indication	Lubrication	Code
E	23.3.2010	P3	W1	P/W1
E	23.3.2010	P1	W2	P/W2
E	23.3.2010	P3	M	P/M
F	22.6.2010	P3	N	P0.3/N
G	22.6.2010	P3	N	P0.2/N

P: Low speed, 4.5 m/min

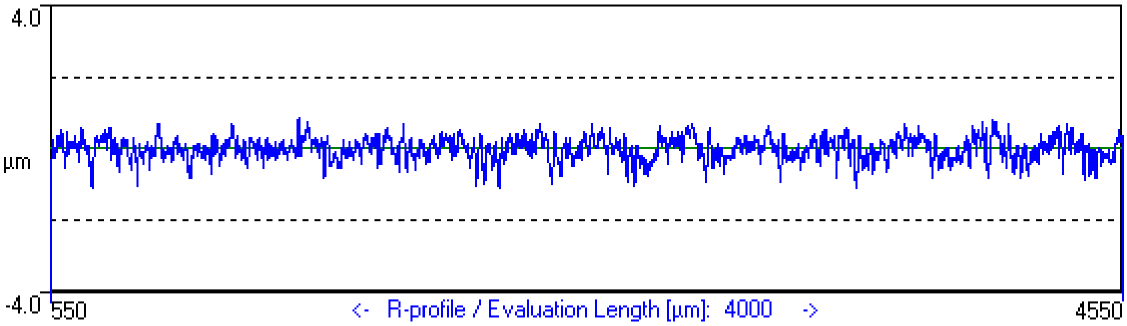
Feed, 0.3 mm/rev (operators C, E and F)
Feed, 0.2 mm/rev (operator G)

Reference surface roughness instrument: Form TalySurf Series 2, Taylor Hobson

Operator C, Date: 19.4.2010, Workpiece P2 – 1% oil concentration (P0.3/W1)

a

File: P2-1%-19-4a.PRF Profile no.: 1 Specimenmark: B2-1-1 7/25/2010

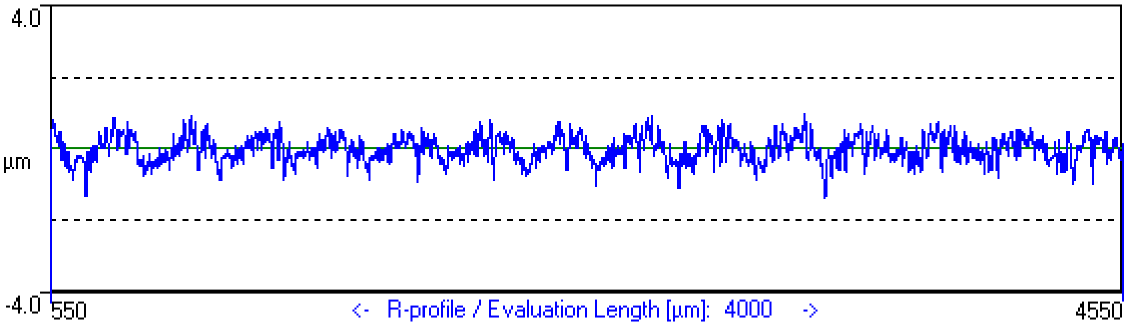


Ra 0.249
Rz 1.780
Rzmax 1.856
RSm 24.144

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

b

File: P2-1%-19-4b.PRF Profile no.: 1 Specimenmark: B2-1-1 7/25/2010

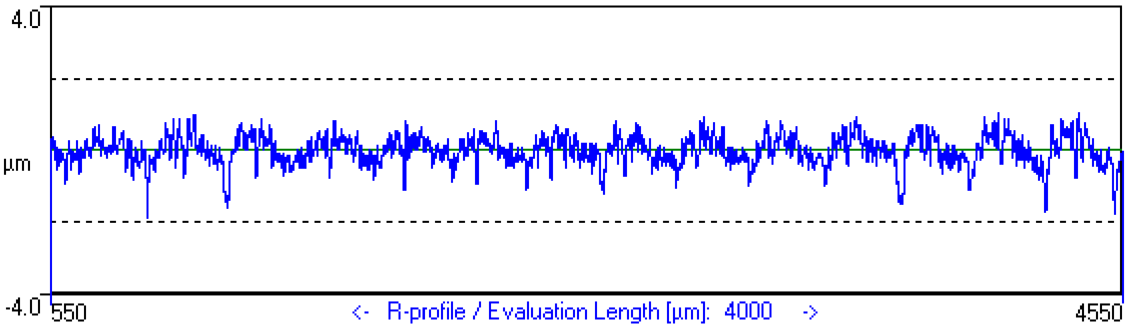


Ra 0.291
Rz 2.010
Rzmax 2.371
RSm 27.348

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

c

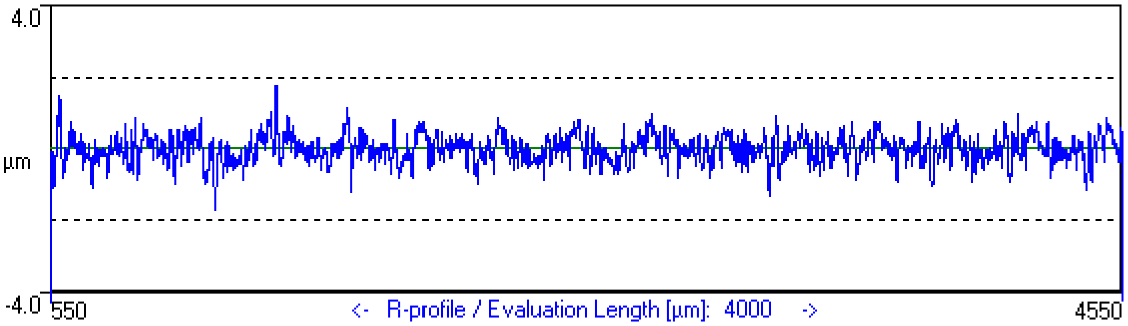
File: P2-1%-19-4c.PRF Profile no.: 1 Specimenmark: B2-1-1 7/25/2010



Ra 0.312
Rz 2.422
Rzmax 2.874
RSm 24.965

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

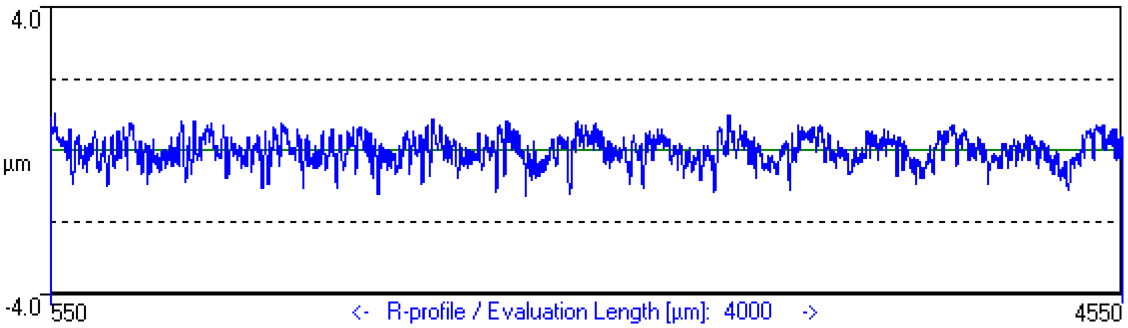
	Operator C, Date: 19.4.2010, Workpiece P1 – 10% oil concentration (P0.3/W2)
a	File: P1-10%-19-4a.PRF Profile no.: 1 Specimenmark: B1-10- 7/25/2010



Ra 0.304
Rz 2.477
Rzmax 3.210
RSm 22.672

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

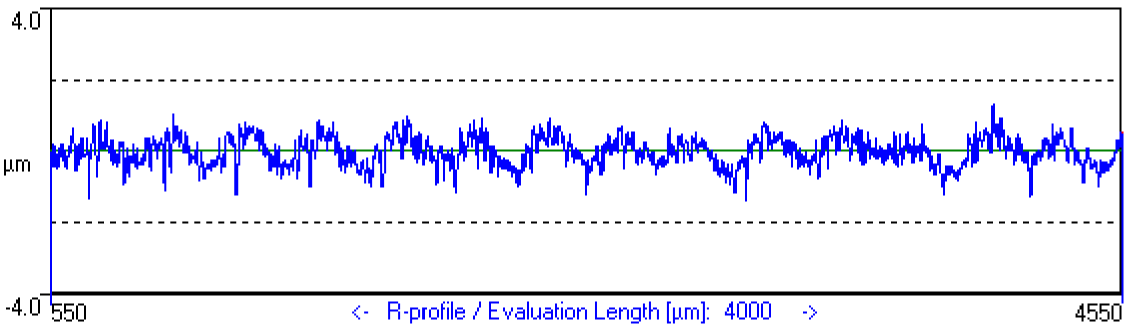
b	File: P1-10%-19-4b.PRF Profile no.: 1 Specimenmark: B1-10- 7/25/2010



Ra 0.307
Rz 2.028
Rzmax 2.134
RSm 24.668

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

c	File: P1-10%-19-4c.PRF Profile no.: 1 Specimenmark: B1-10- 7/25/2010



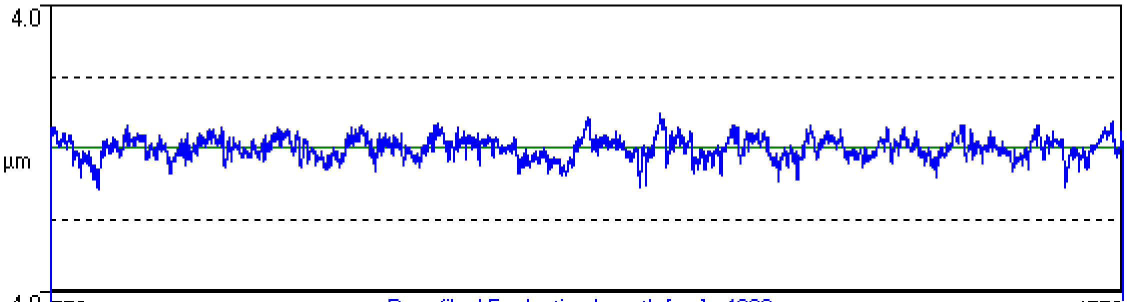
Ra 0.328
Rz 2.295
Rzmax 2.582
RSm 30.958

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

Operator C, Date: 19.4.2010, Workpiece P1 –oil (P0.3/M)

a

File: P1-oil-19-4a.PRF Profile no.: 1 Specimenmark: B1-oil 7/25/2010



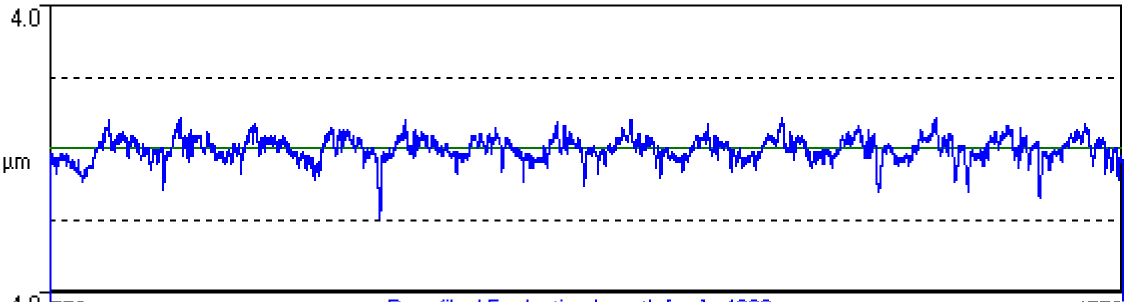
550 <- R-profile / Evaluation Length [µm]: 4000 -> 4550

Ra 0.244
Rz 1.723
Rzmax 2.064
RSm 34.825

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

b

File: P1-oil-19-4b.PRF Profile no.: 1 Specimenmark: B1-oil 7/25/2010



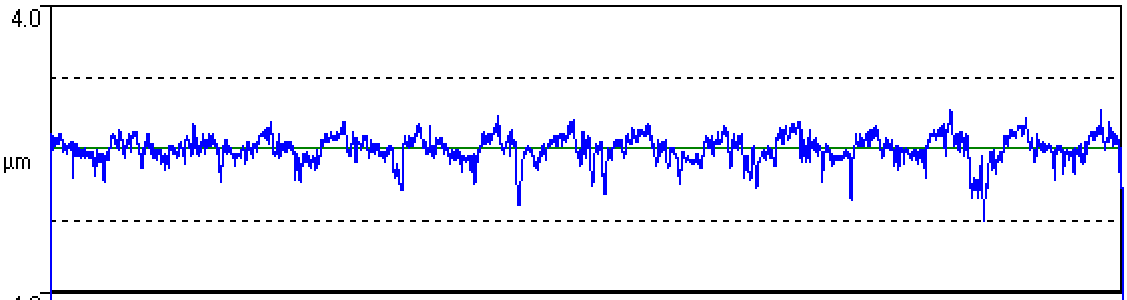
550 <- R-profile / Evaluation Length [µm]: 4000 -> 4550

Ra 0.256
Rz 2.179
Rzmax 2.749
RSm 41.492

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

c

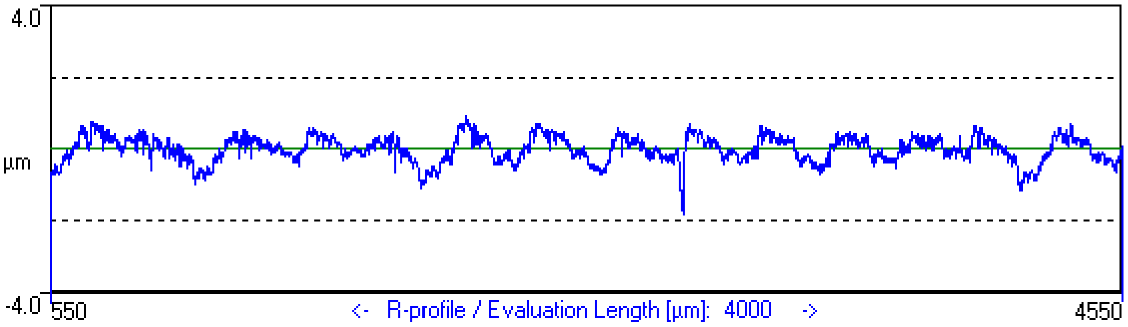
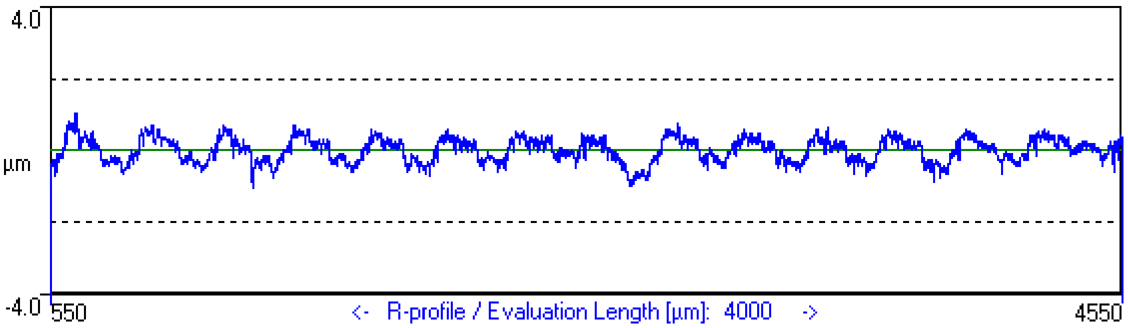
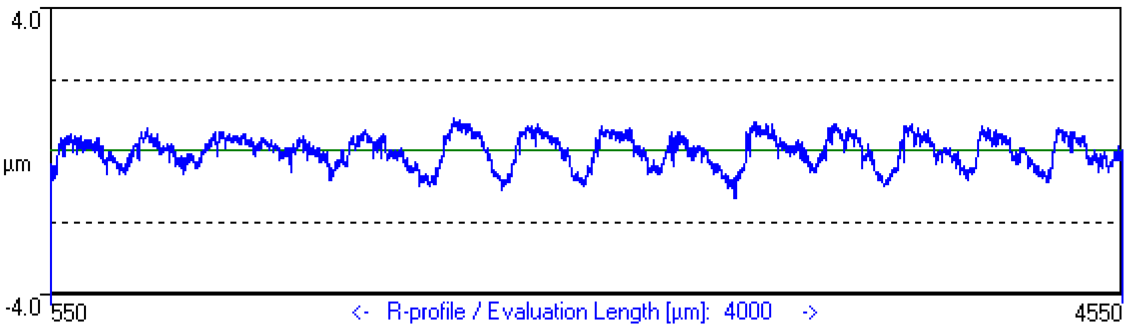
File: P1-oil-19-4c.PRF Profile no.: 1 Specimenmark: B1-oil 7/25/2010



550 <- R-profile / Evaluation Length [µm]: 4000 -> 4550

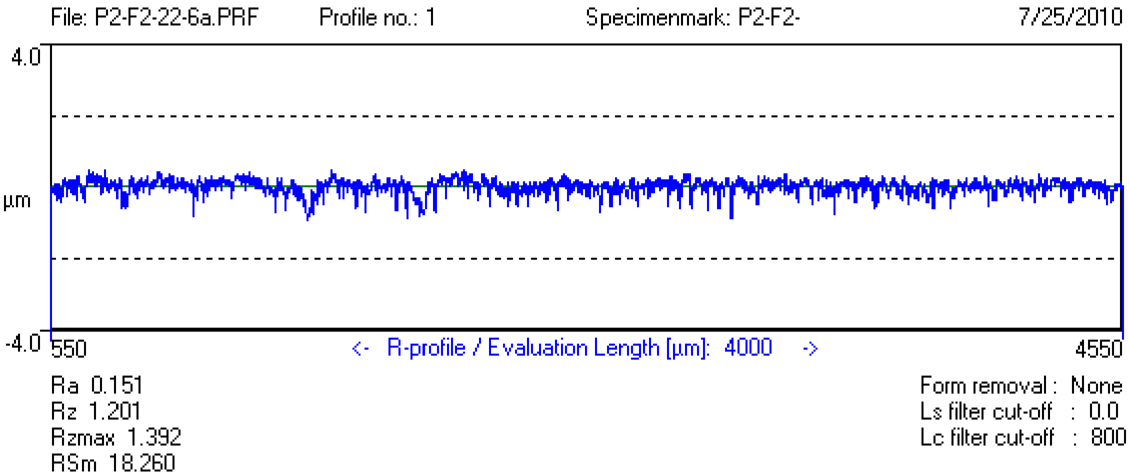
Ra 0.285
Rz 2.253
Rzmax 3.072
RSm 44.420

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

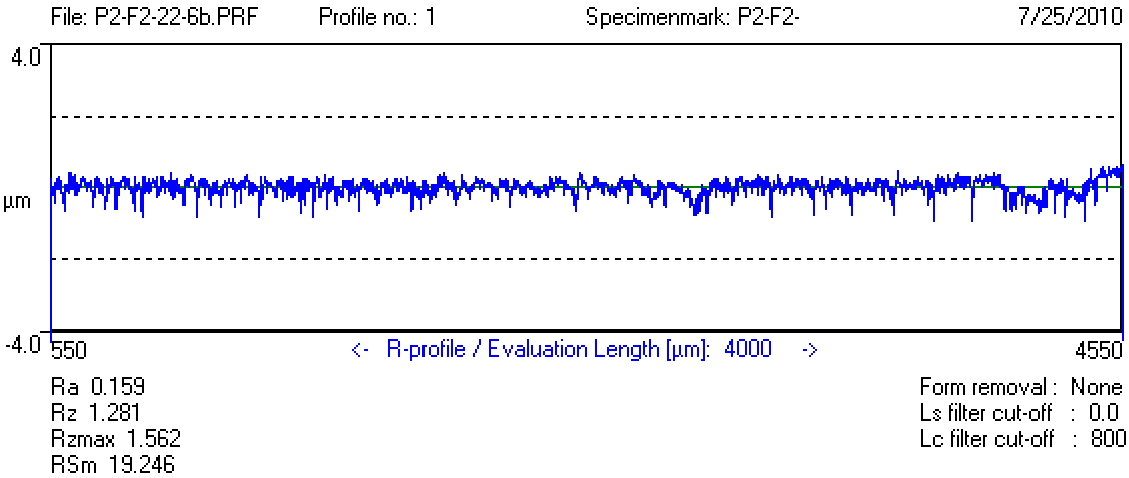
	Operator F, Date: 22.6.2010, Workpiece P2 – neat oil (P0.3/N)
a	File: P2-F3-22-6a.PRF Profile no.: 1 Specimenmark: P2-F3- 7/25/2010  Ra 0.290 Rz 1.905 Rzmax 2.538 RSm 59.027 Form removal : None Ls filter cut-off : 0.0 Lc filter cut-off : 800
b	File: P2-F3-22-6b.PRF Profile no.: 1 Specimenmark: P2-F3- 7/25/2010  Ra 0.279 Rz 1.620 Rzmax 2.061 RSm 66.428 Form removal : None Ls filter cut-off : 0.0 Lc filter cut-off : 800
c	File: P2-F3-22-6c.PRF Profile no.: 1 Specimenmark: P2-F3- 7/25/2010  Ra 0.349 Rz 1.782 Rzmax 2.122 RSm 51.941 Form removal : None Ls filter cut-off : 0.0 Lc filter cut-off : 800

Operator G, Date: 22.6.2010, Workpiece P2 – neat oil (P0.2/N)

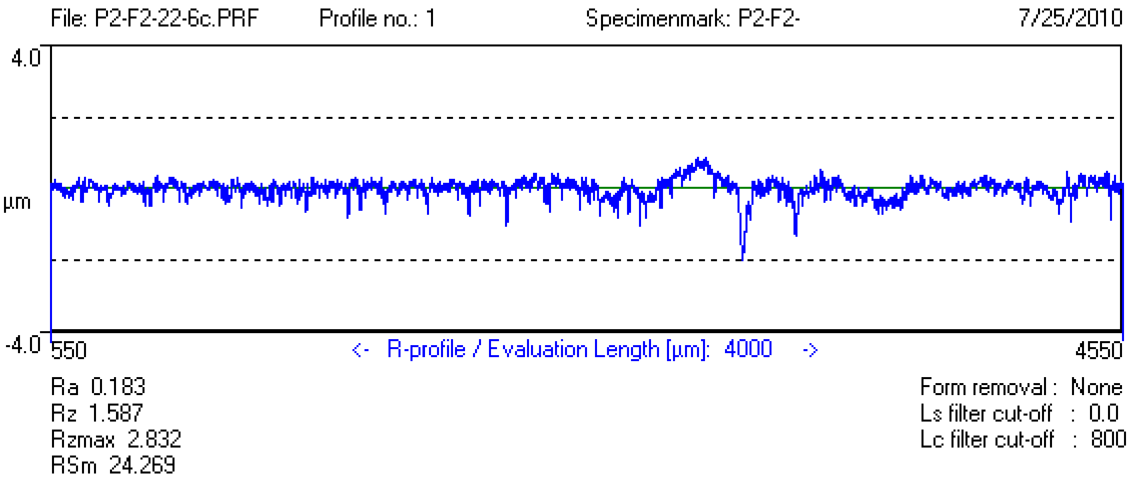
a



b



c

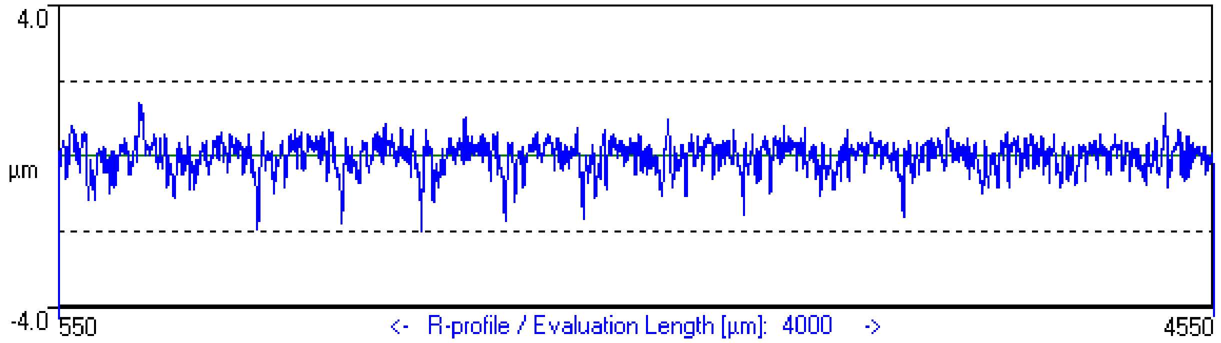


Reference surface roughness instrument: RTH TalySurf 5-120, Taylor Hobson

Operator E, Date: 23.3.2010, Workpiece P3 – 1% oil concentration (P0.3/W1)

a

File: EP3_1.DAT Profile no.: 1 Specimenmark: P1 5/10/2011

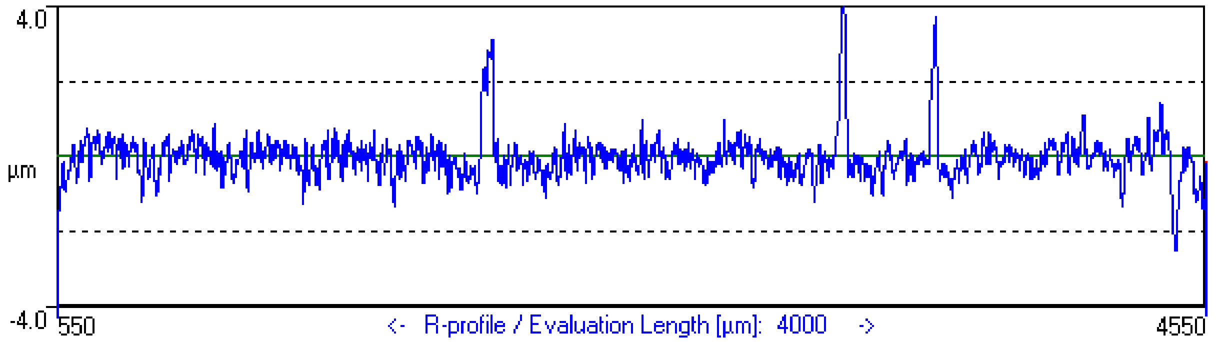


Ra 0.306
Rz 2.669
Rzmax 3.325

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

b

File: EP3_1.DAT Profile no.: 2 Specimenmark: P1 5/10/2011

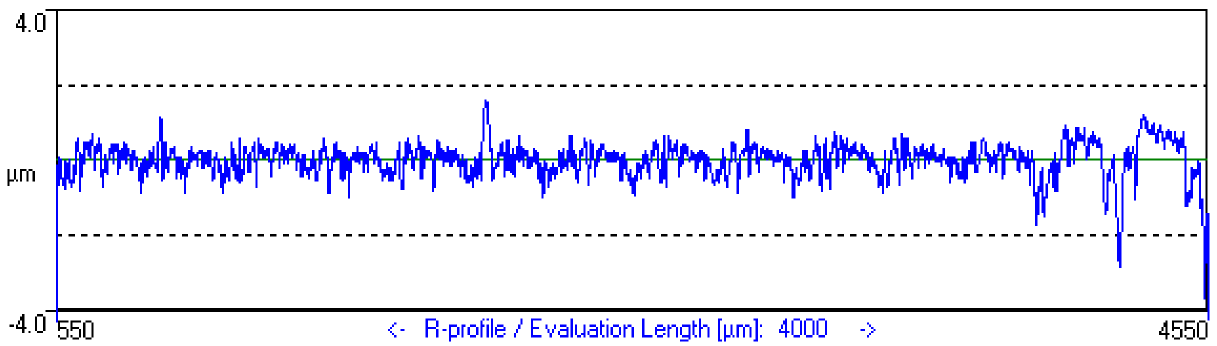


Ra 0.372
Rz 3.623
Rzmax 5.271

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

c

File: EP3_1.DAT Profile no.: 3 Specimenmark: P1 5/10/2011

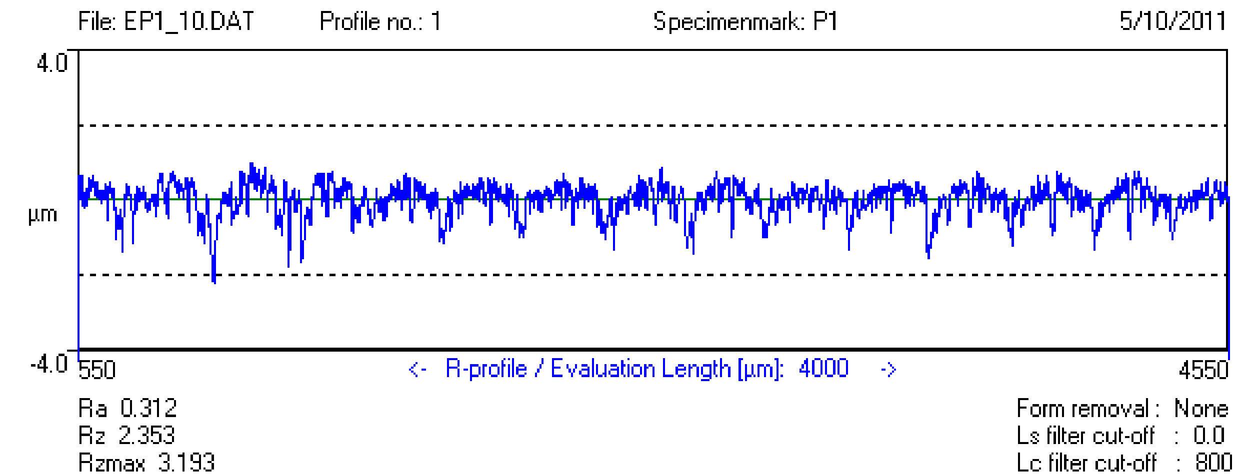


Ra 0.323
Rz 2.593
Rzmax 4.873

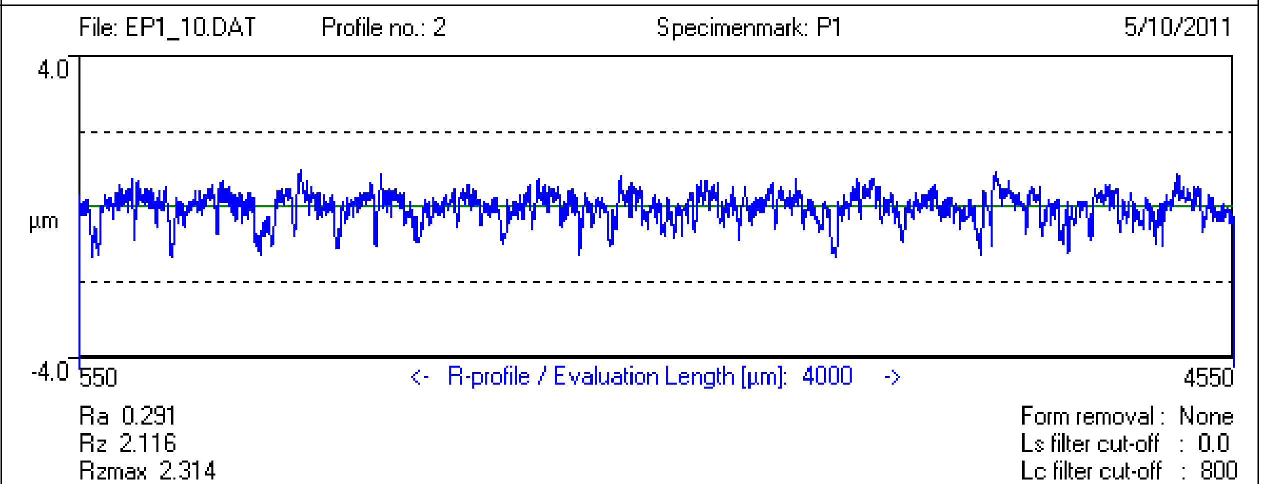
Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

Operator E, Date: 23.3.2010, Workpiece P1 – 10% oil concentration (P0.3/W2)

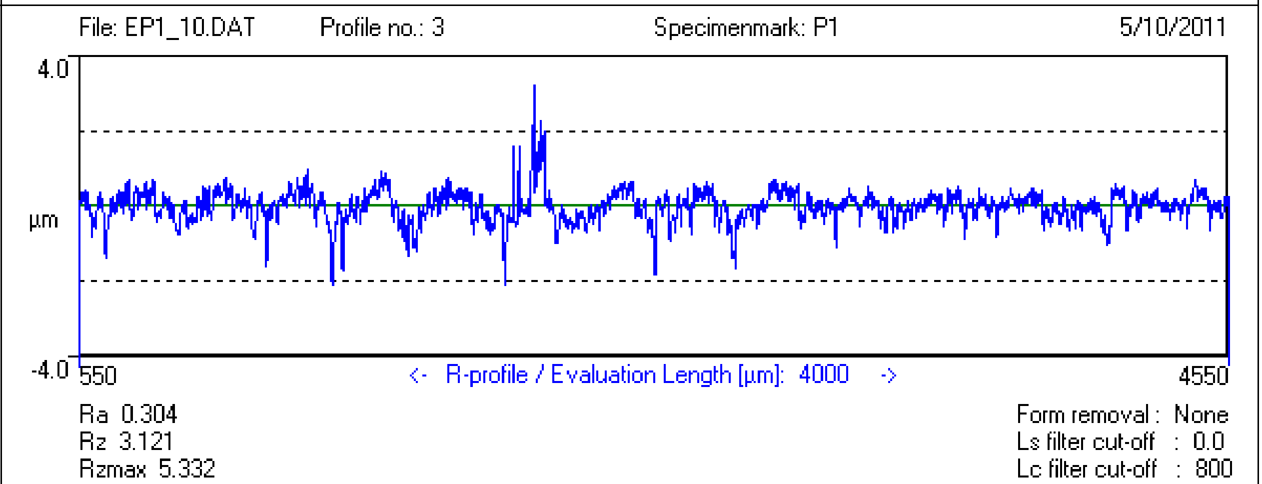
a



b

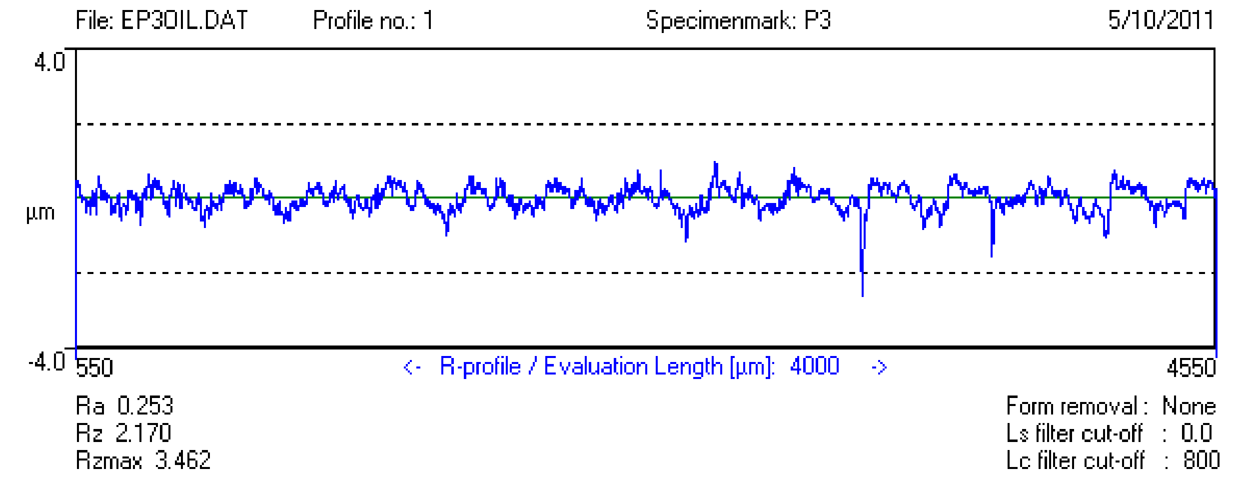


c

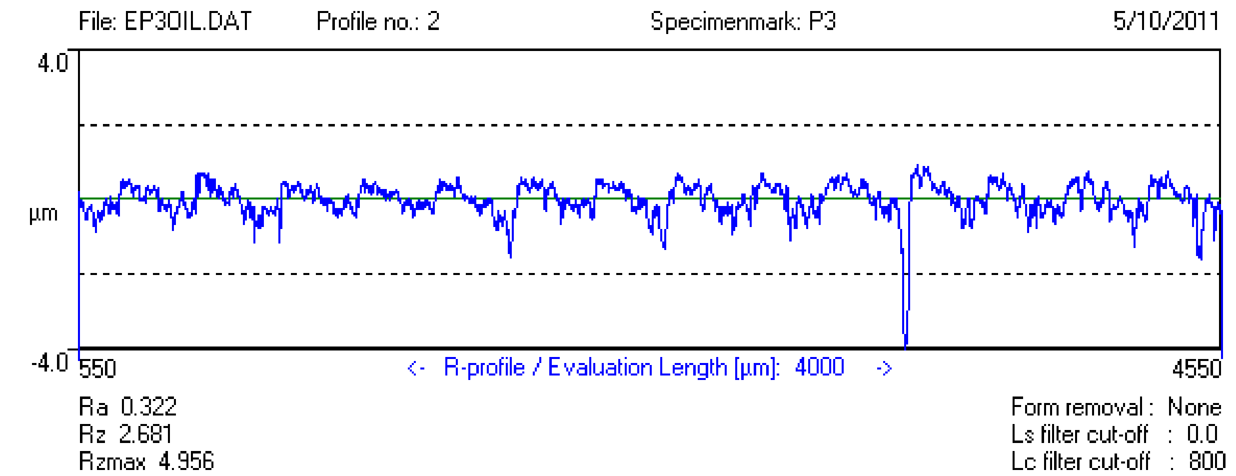


Operator E, Date: 23.3.2010, Workpiece P3 –oil (P0.3/M)

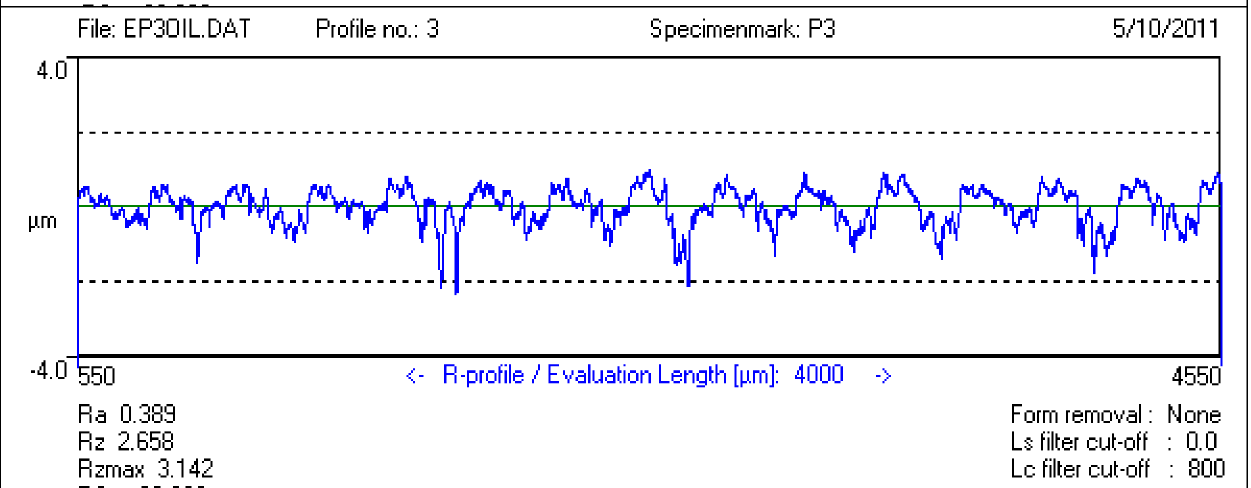
a



b

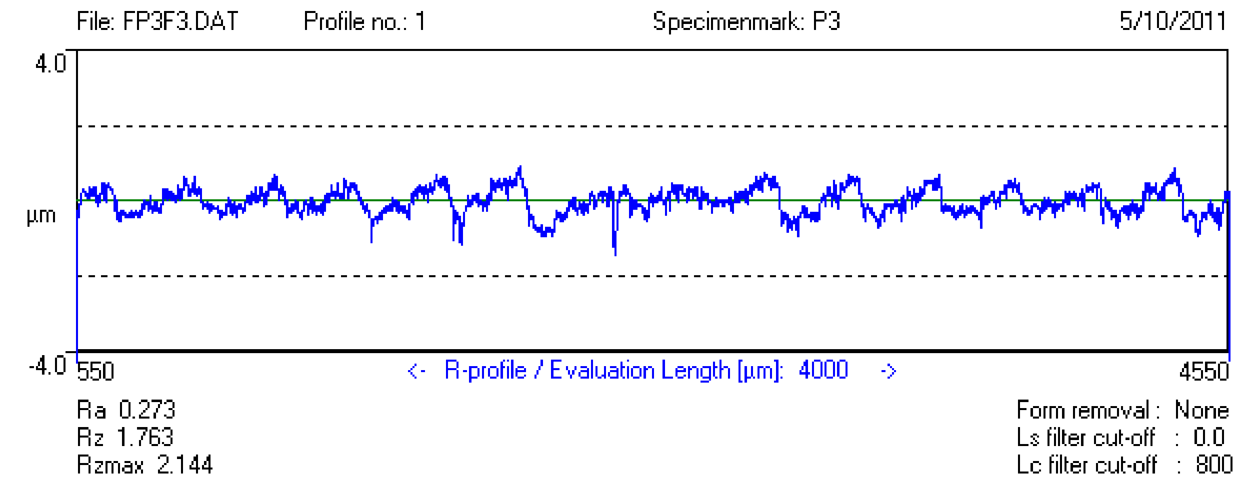


c

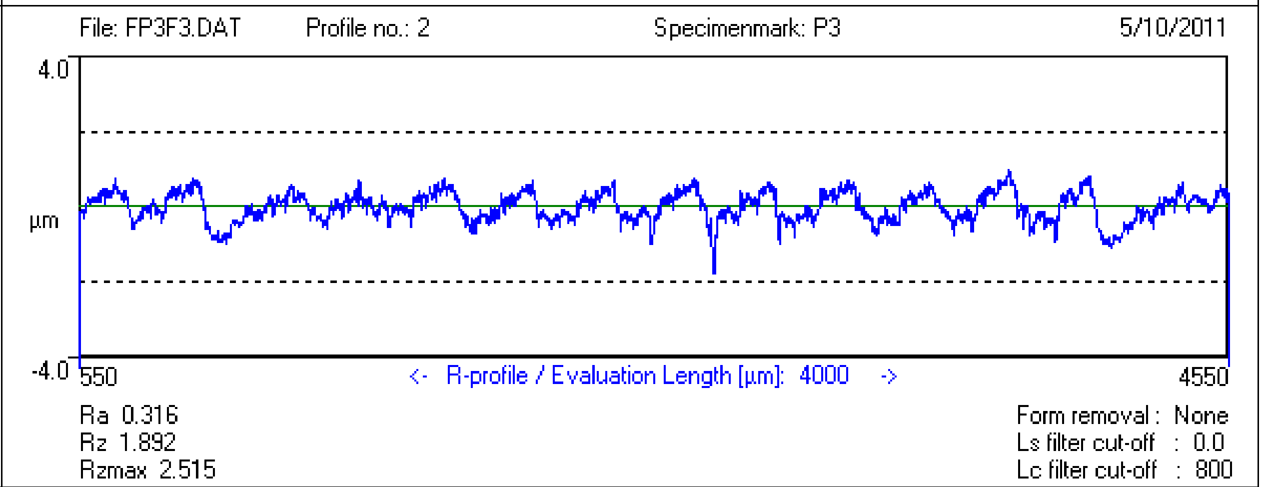


Operator F, Date: 22.6.2010, Workpiece P3 – neat oil (P0.3/N)

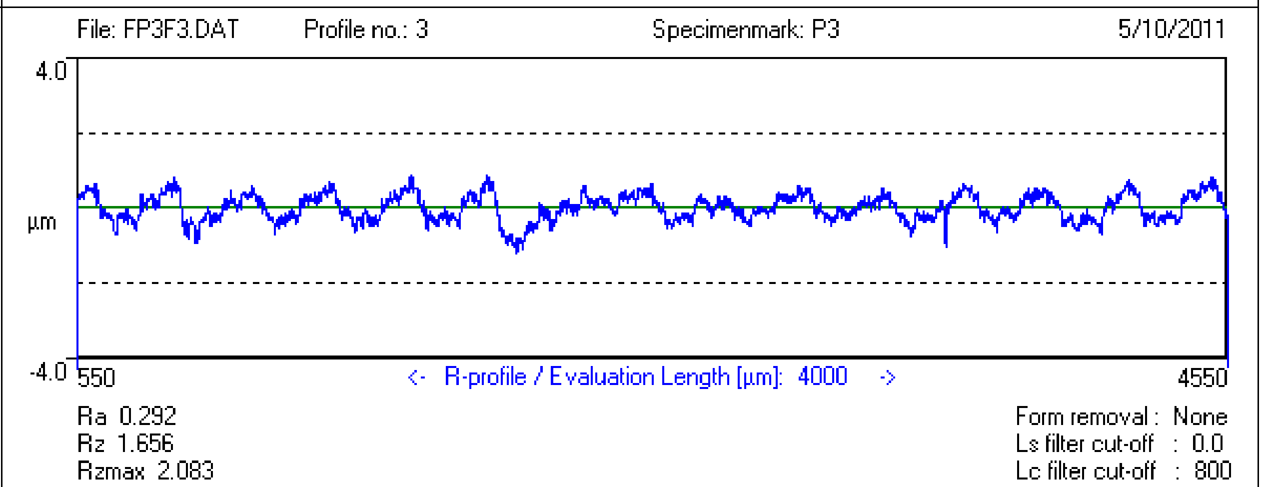
a

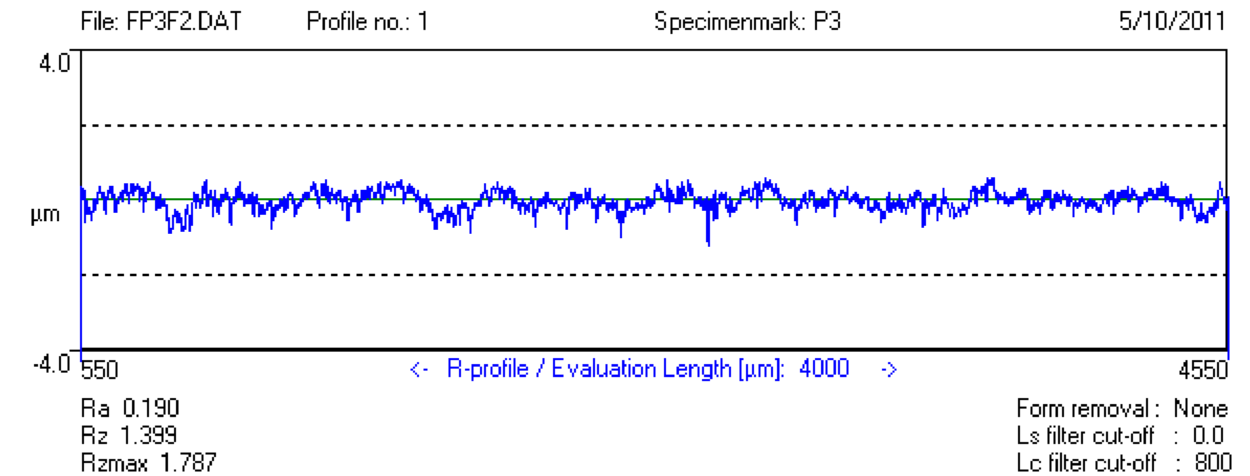
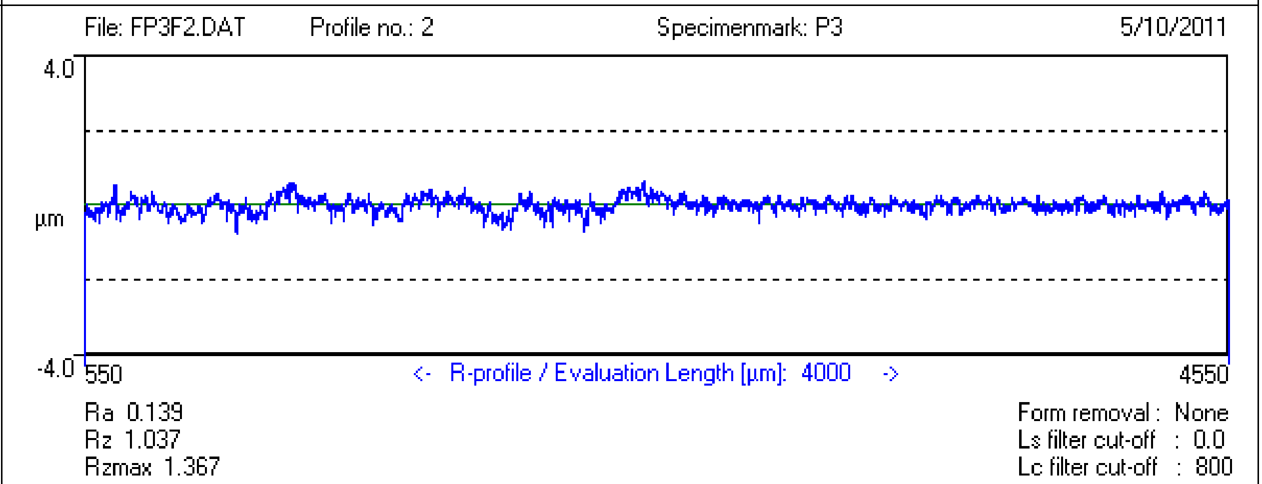
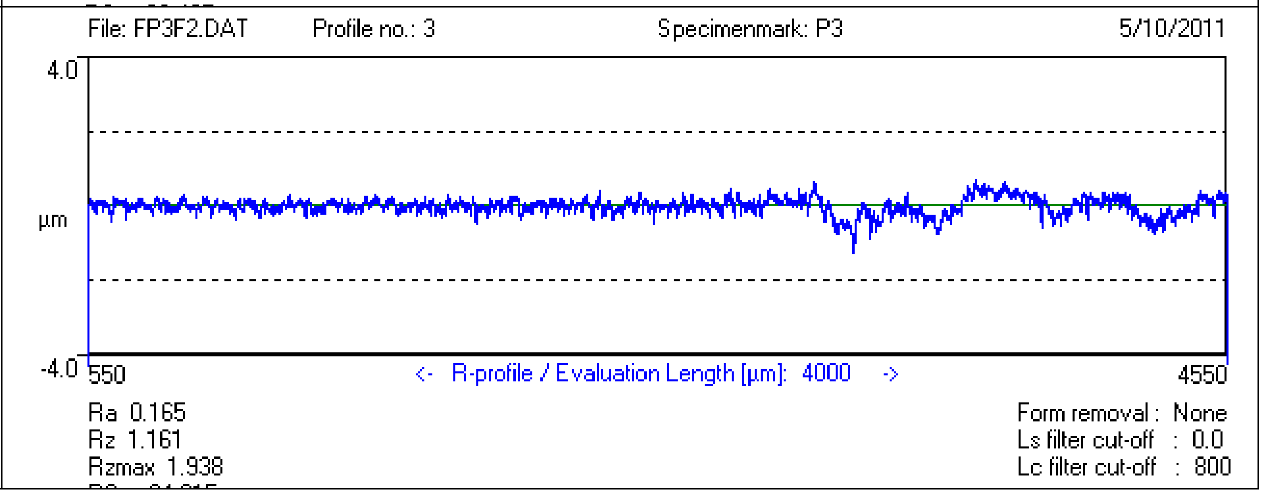


b



c



	Operator G, Date: 22.6.2010, Workpiece P3 – neat oil (P0.2/N)
a	
b	
c	

Appendix D

3D reference measurements

Appendix D contains profiles of 3D reference measurements which were performed by Rene Sobiecki. The instrument was TalySurf 2, Taylor Hobson.

Table D.1: Measured workpieces.

Operator	Date	WP indication	Lubrication	Code
C	19.4.2010	P2	W1	P/W1
C	19.4.2010	P1	W2	P/W2
C	19.4.2010	P1	M	P/M
F	22.6.2010	P2	N	P0.3/N
G	22.6.2010	P2	N	P0.2/N

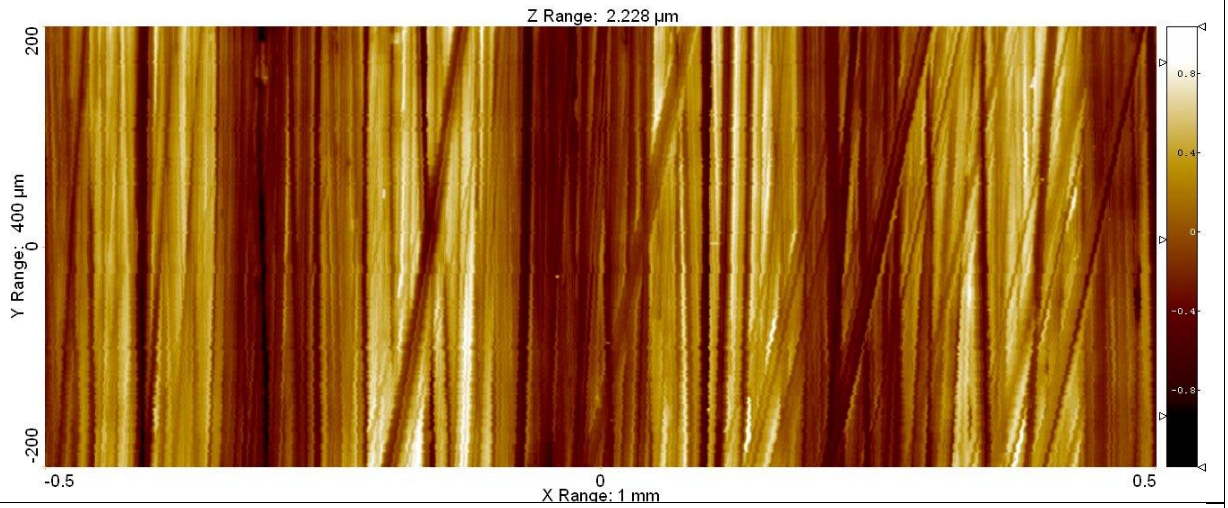
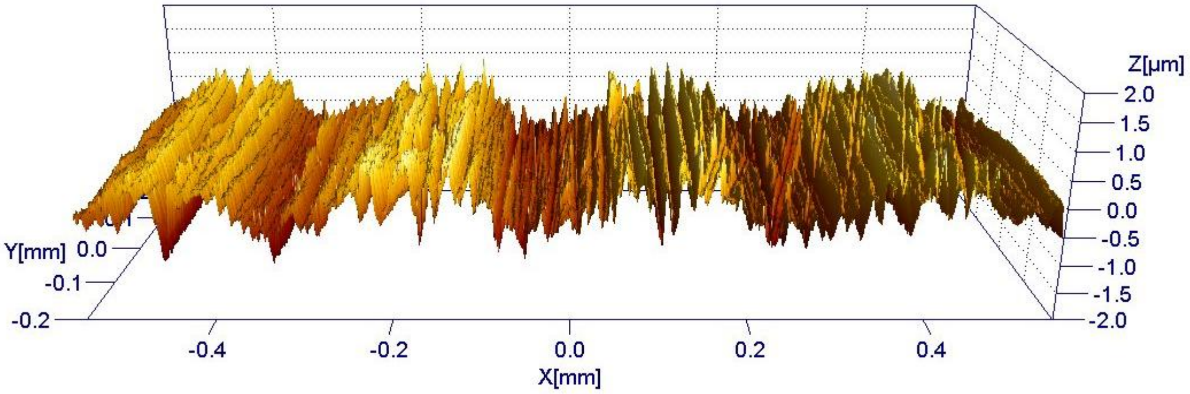
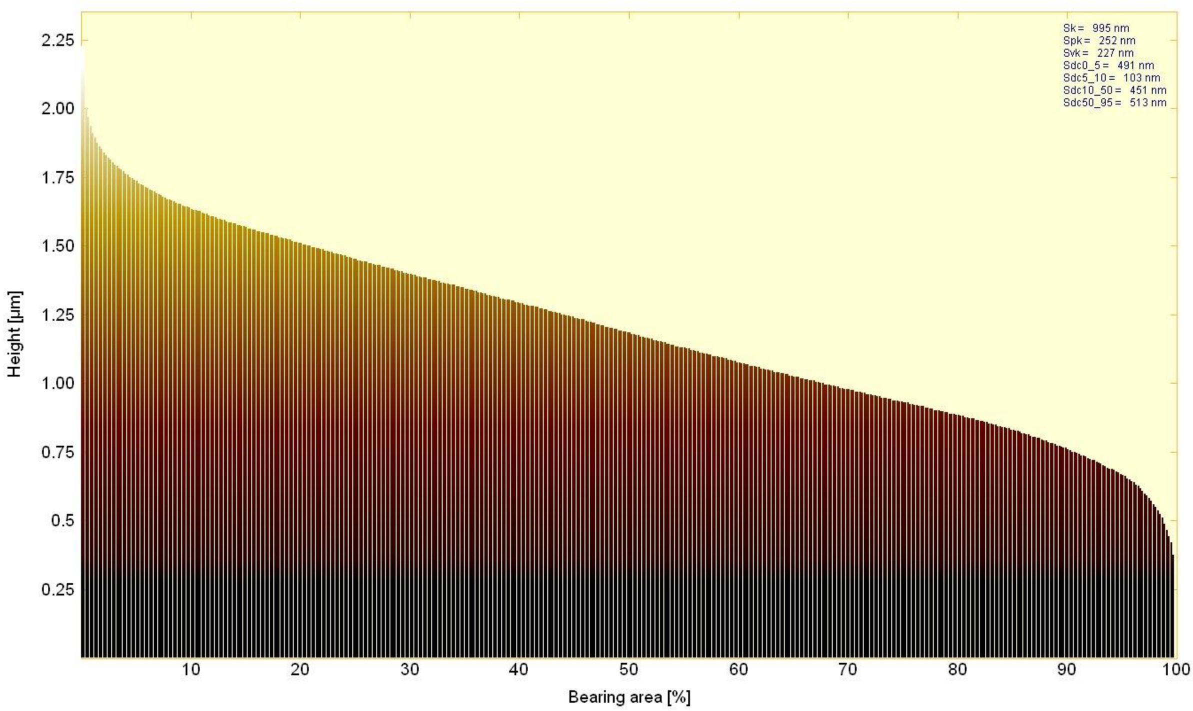
Numbers 1, 2, 3 in the table starting on the following page correspond to a following:

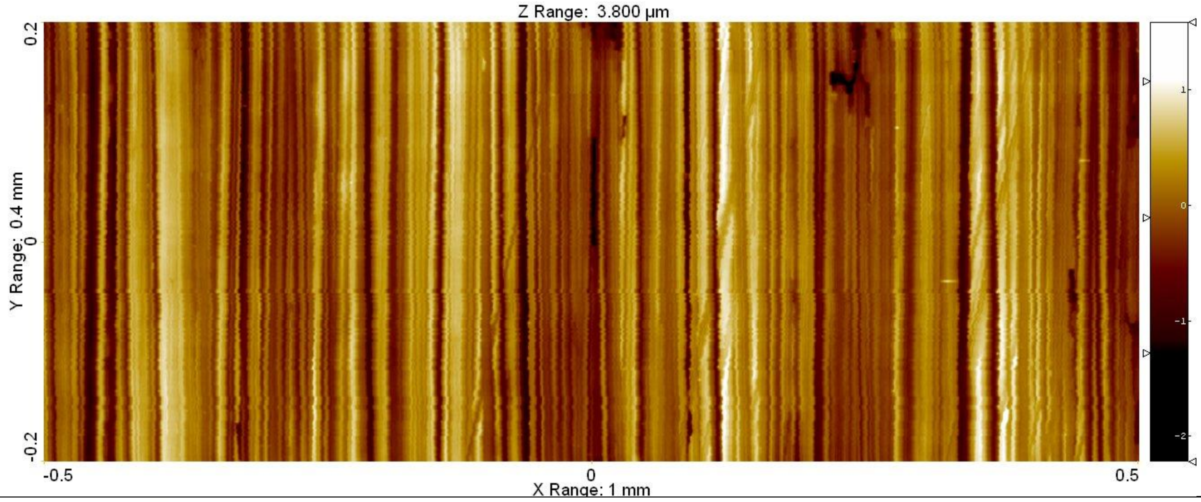
- 1 - top view
- 2 - 3D view
- 3 - bearing ratio curve

Measuring strategy is according to Figure 2.6(d).

P: Low speed, 4.5 m/min

Feed, 0.3 mm/rev (operators C and F)
Feed, 0.2 mm/rev (operator G)

<table>
<tr><th></th><th>Operator C, Date: 19.4.2010, Workpiece P2 – 1% oil concentration (P0.3/W1)</th></tr>
<tr><td>1</td><td>
</td></tr>
<tr><td>2</td><td>
</td></tr>
<tr><td>3</td><td>
</td></tr>
</table>

<table>
<tr><th></th><th>Operator C, Date: 19.4.2010, Workpiece P1 – 10% oil concentration (P0.3/W2)</th></tr>
<tr><td>1</td><td>
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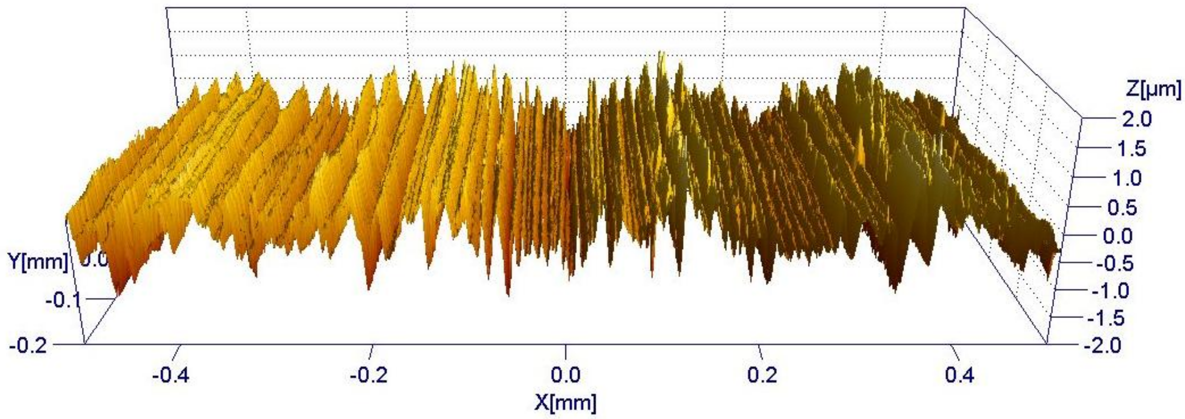
<tr><td>2</td><td>
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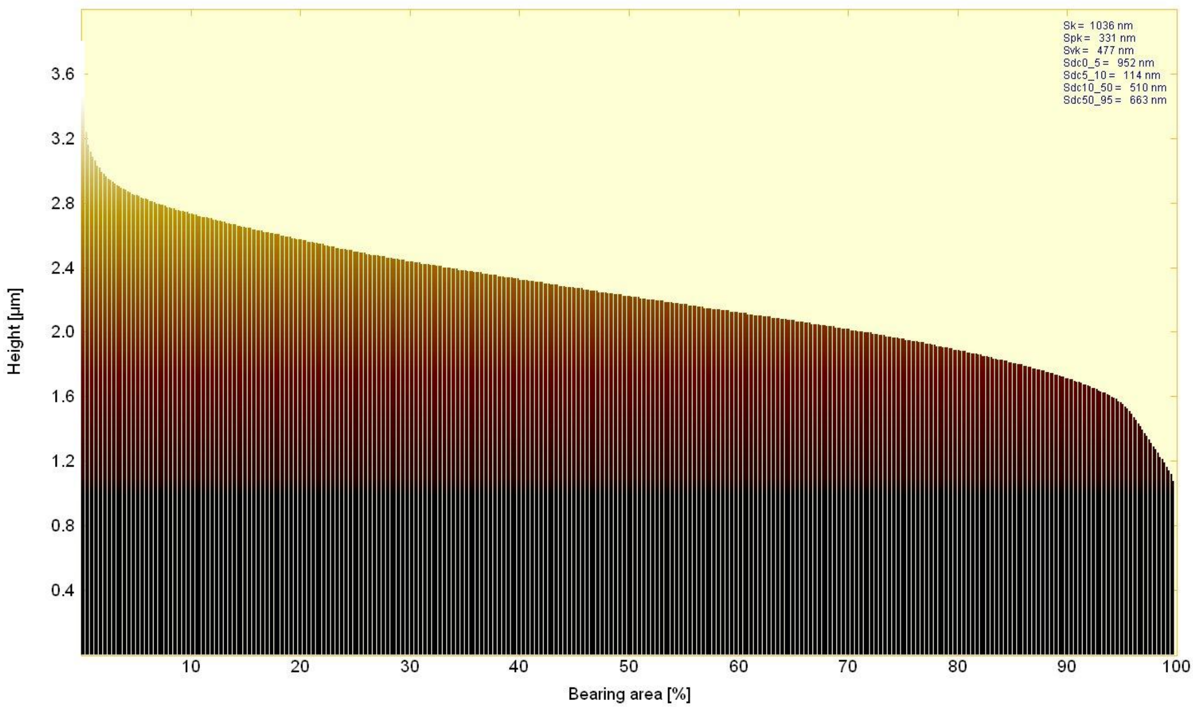
<tr><td>3</td><td>
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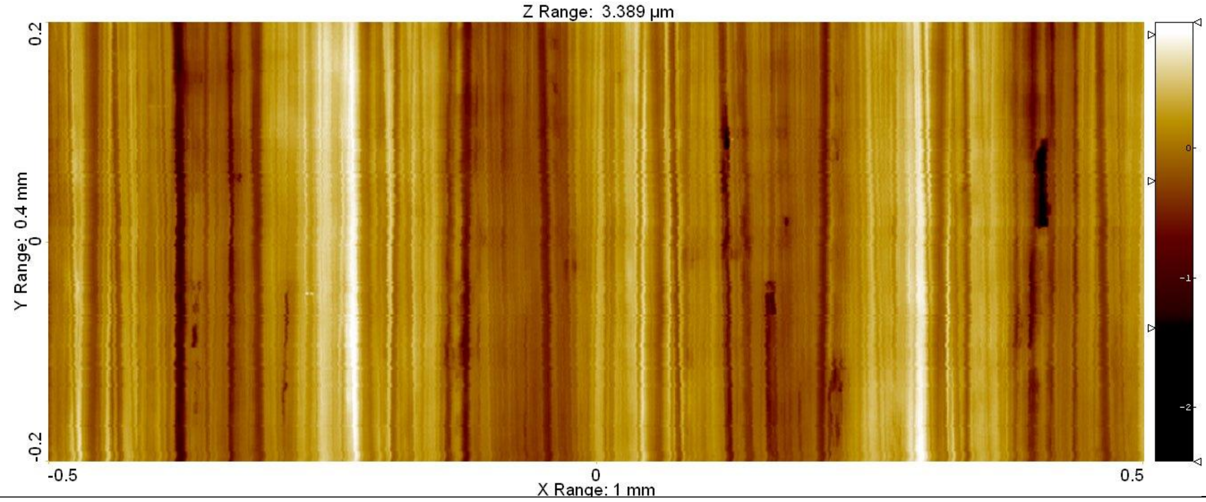
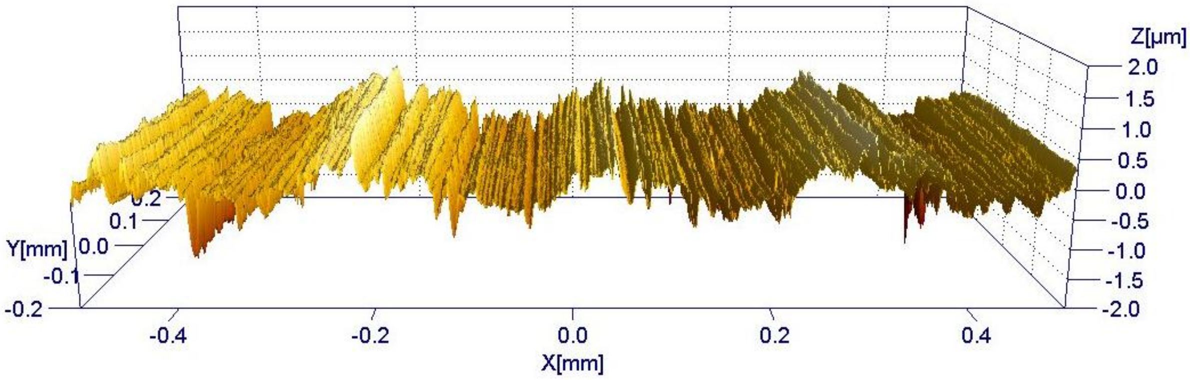
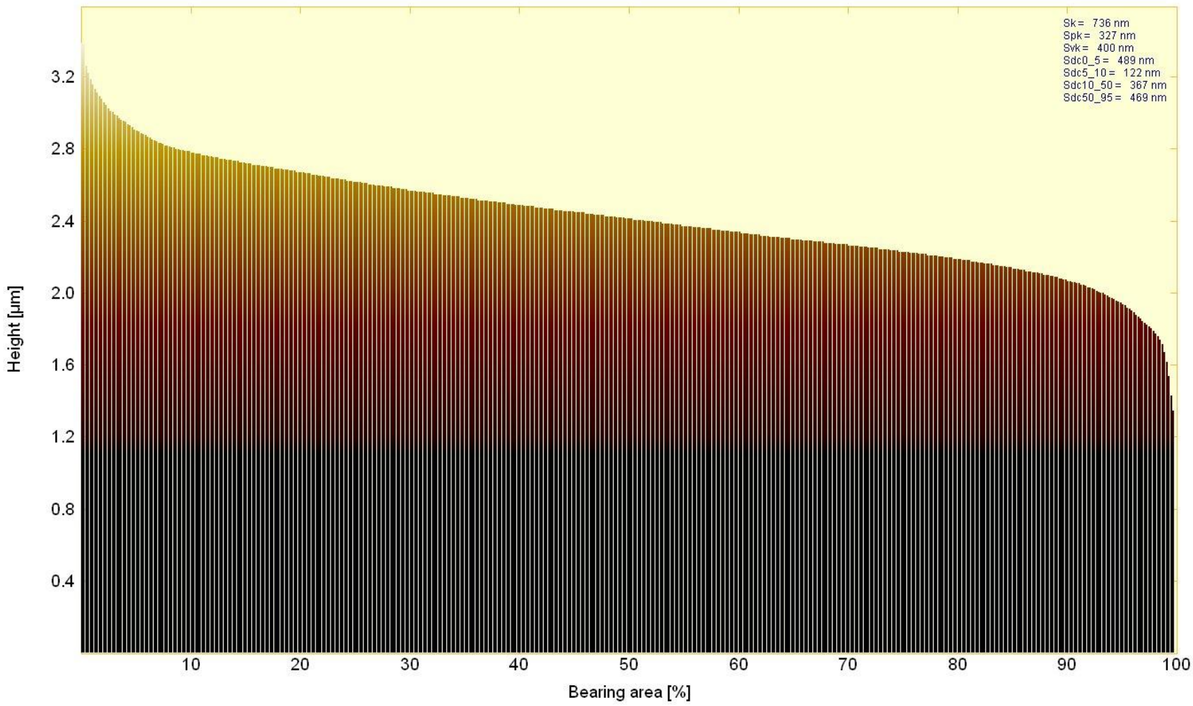
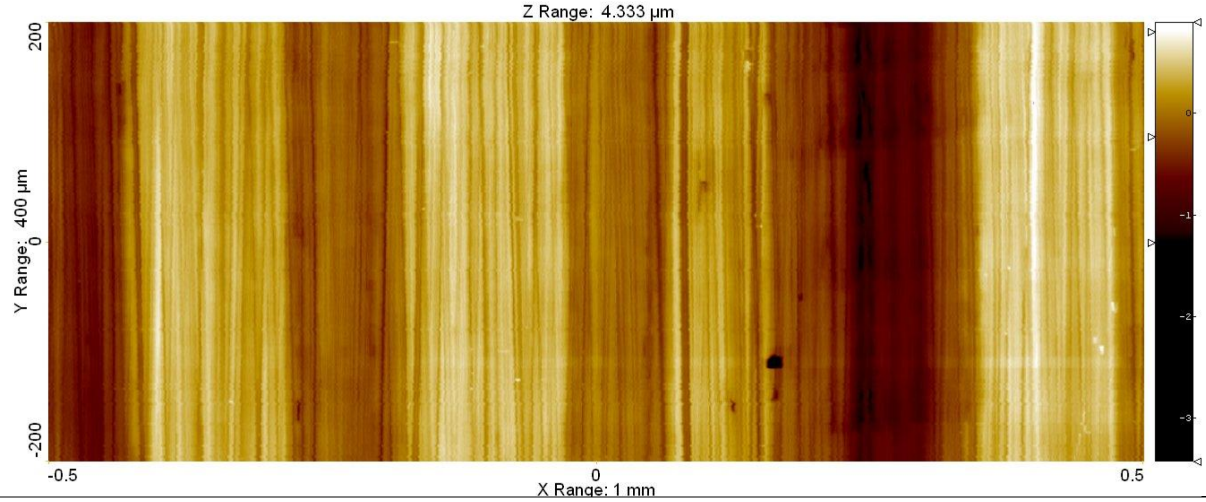
	Operator C, Date: 19.4.2010, Workpiece P1 –mineral oil (P0.3/M)
1	
2	
3	

<table>
<tr><th></th><th>Operator F, Date: 22.6.2010, Workpiece P2 – neat oil (P0.3/N)</th></tr>
<tr><td>1</td><td>
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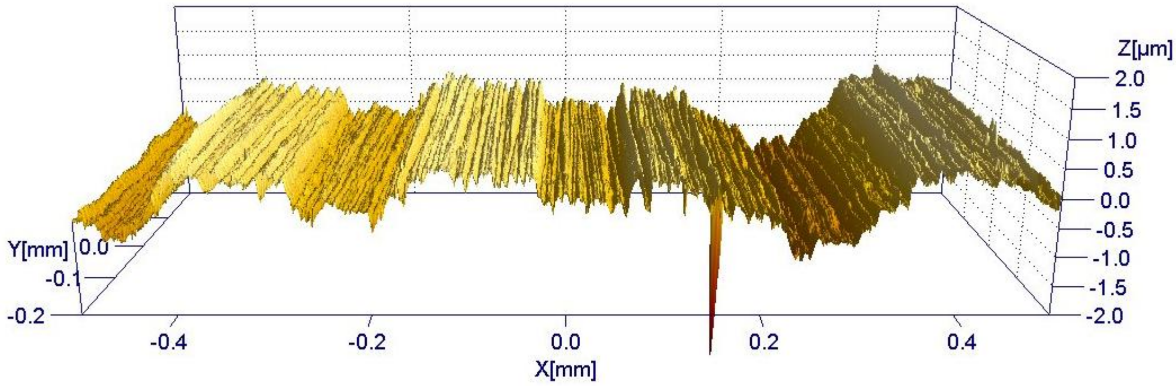
<tr><td>2</td><td>
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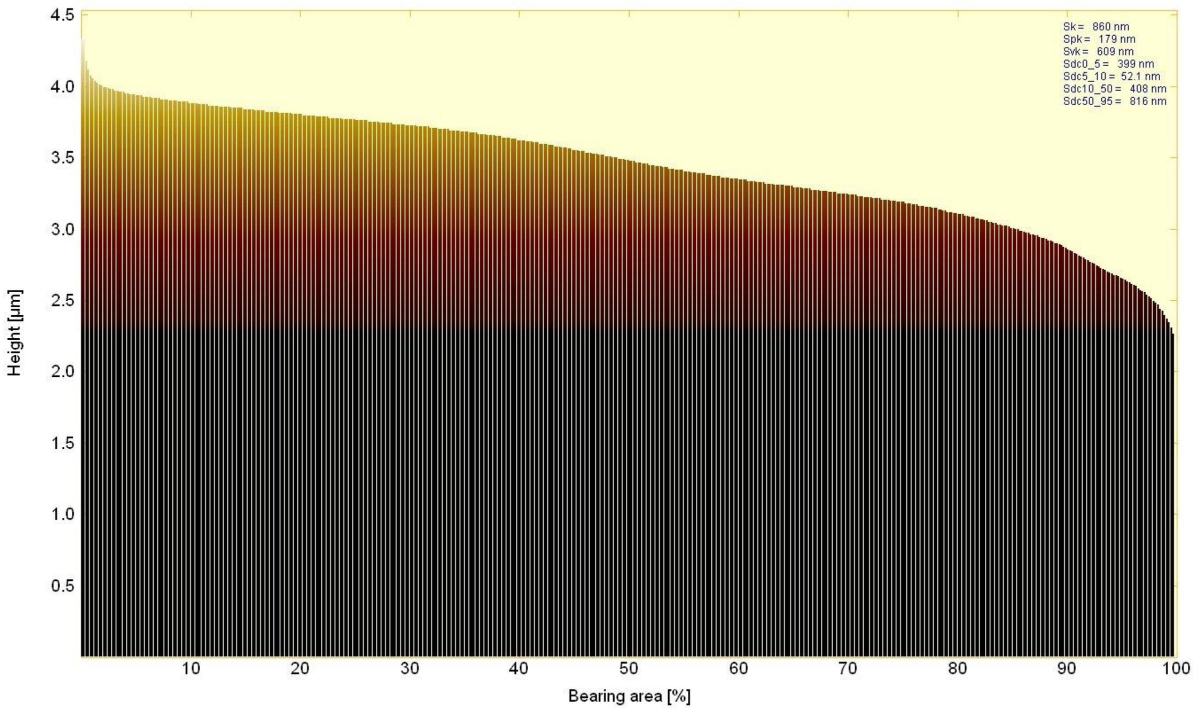
<tr><td>3</td><td>
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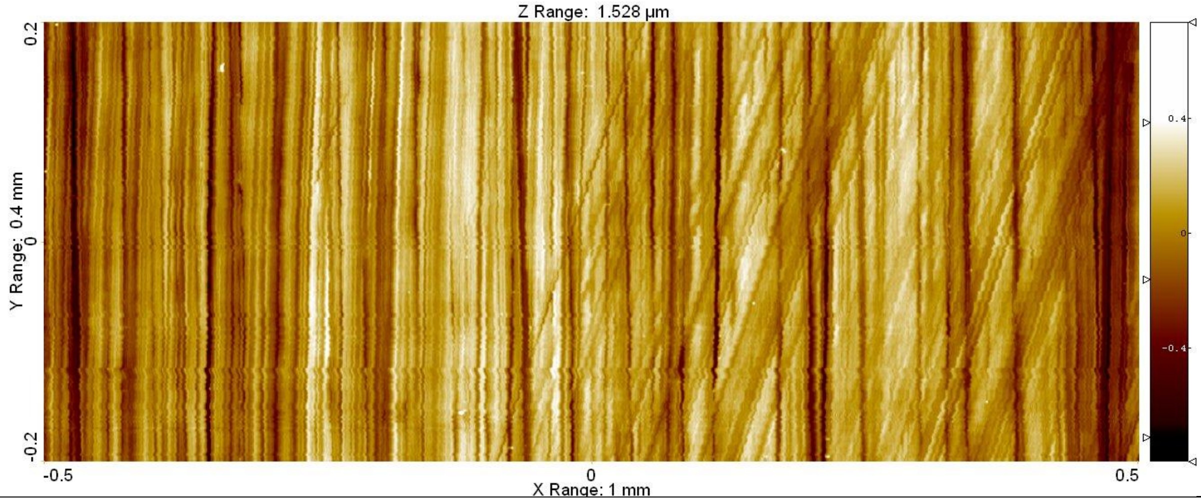
<table>
<tr><th></th><th>Operator G, Date: 22.6.2010, Workpiece P2 – neat oil (P0.2/N)</th></tr>
<tr><td>1</td><td>
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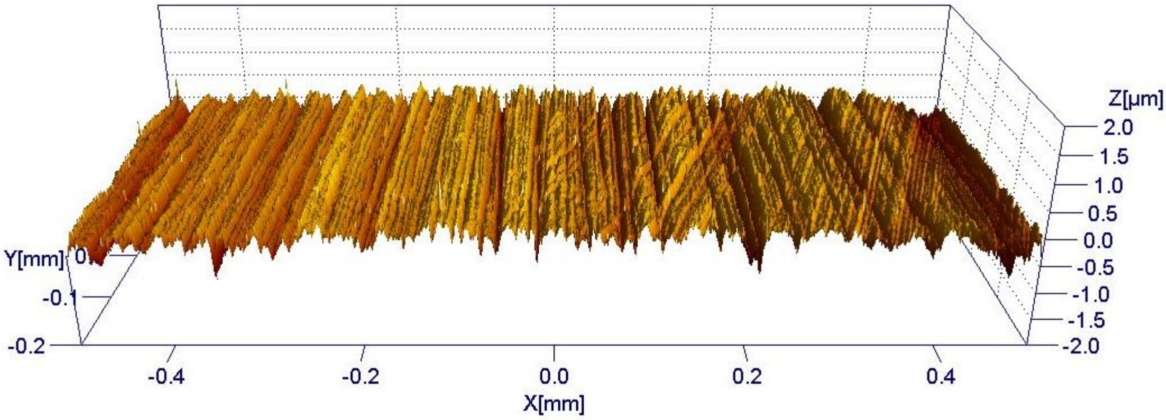
<tr><td>2</td><td>
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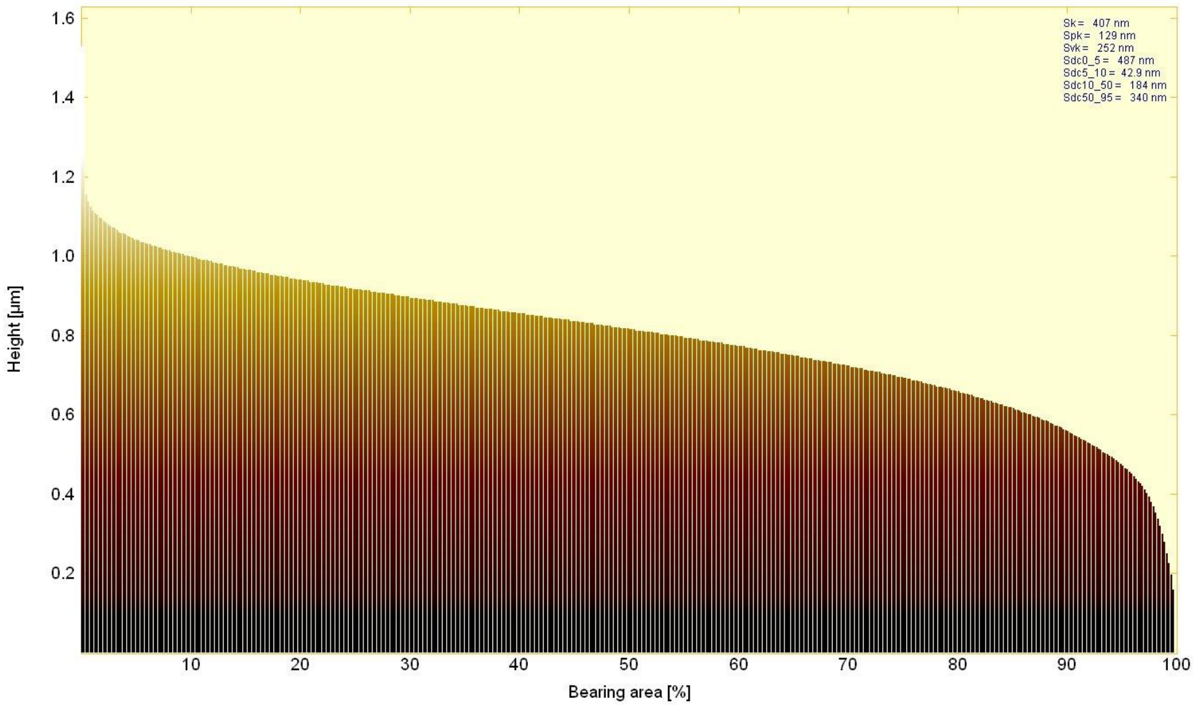
<tr><td>3</td><td>
</td></tr>
</table>

Appendix E

Surface roughness profiles as feed marks from a cutting tool

Appendix E contains profiles of a length 0.3 mm corresponding to a feed mark from the cutting tool. The correct feed was however measured to be 0.279 mm/rev as explained in Section 2.5.

Table E.1: Selected profiles for two lubrications.

Lubrication	W1		M	
Operator	WP	Profile #	WP	Profile #
B	P3	4	P3	2
	R3	3	R1	4
C	P2	4	P1	3
	R2	4	R1	1
A	P1	2	P3	4
	R2	2	R1	1
D	P2	2	P1	1
	R3	1	R1	1

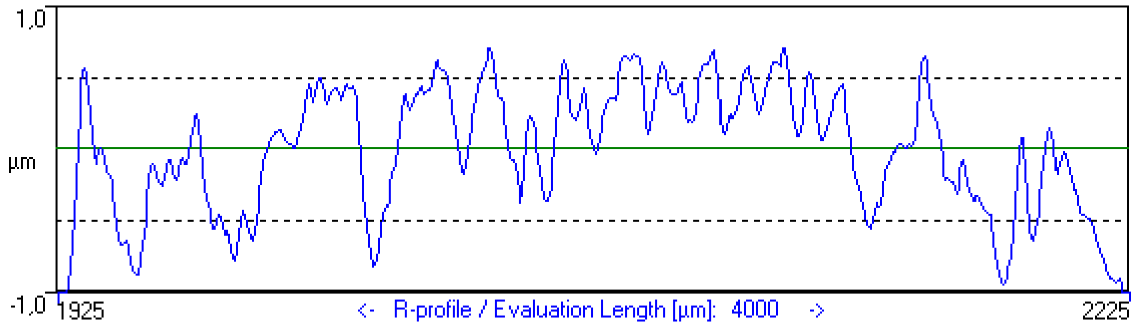
P: Low speed, 4.5 m/min
R: High speed, 10.2 m/min

Feed, 0.3 mm/rev

Appendix E1: Surface roughness profiles corresponding to feed marks of a cutting tool – W1 lubrication

Operator B, Date: 12.4.2010, Workpiece P3 – 1% oil concentration (P0.3/W1)

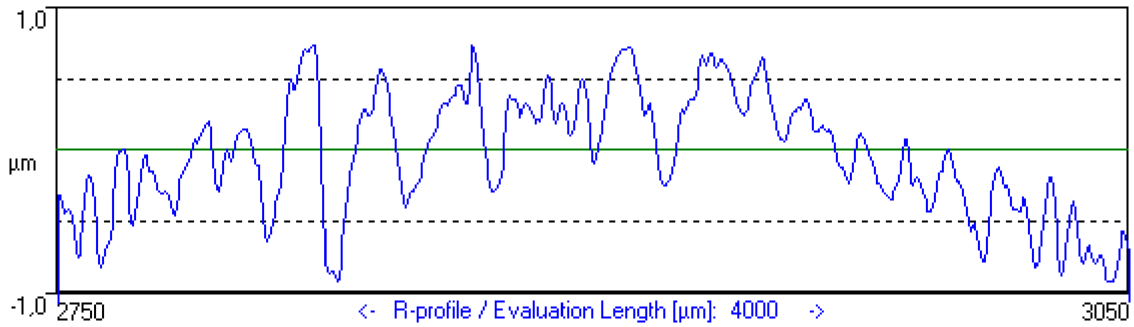
File: P3_1%.dat.dat Profile no.: 4 Specimenmark: 0393341 14-06-2010



Ra 0,391
Rz 2,622
Rzmax 3,120
RSm 29,219

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: P3_1%.dat.dat Profile no.: 4 Specimenmark: 0393341 14-06-2010

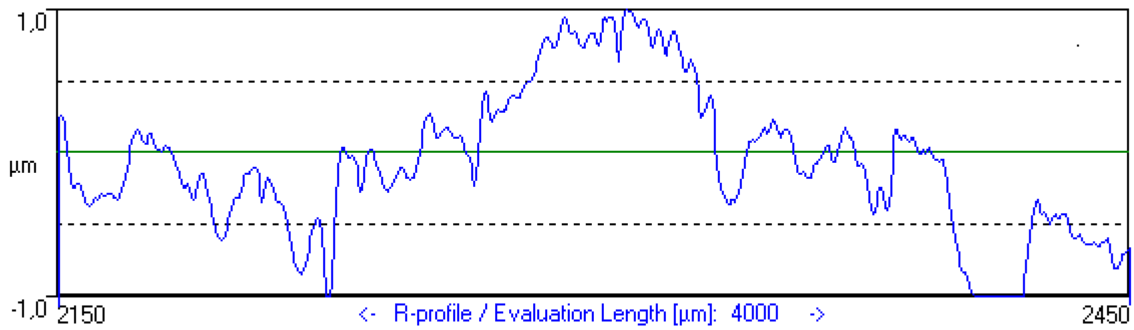


Ra 0,391
Rz 2,622
Rzmax 3,120
RSm 29,219

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator B, Date: 12.4.2010, Workpiece R3 – 1% oil concentration (R0.3/W1)

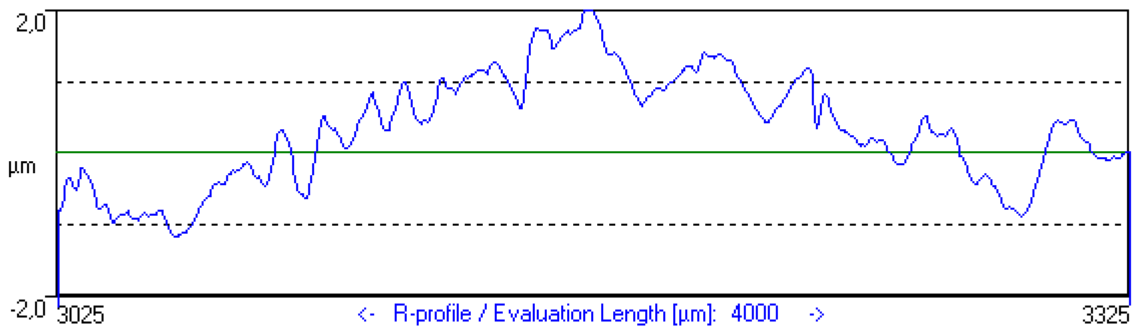
File: R3_1%.dat Profile no.: 3 Specimenmark: 0393341 14-06-2010



Ra 0,655
Rz 4,522
Rzmax 5,730
RSm 55,623

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: R3_1%.dat Profile no.: 3 Specimenmark: 0393341 14-06-2010

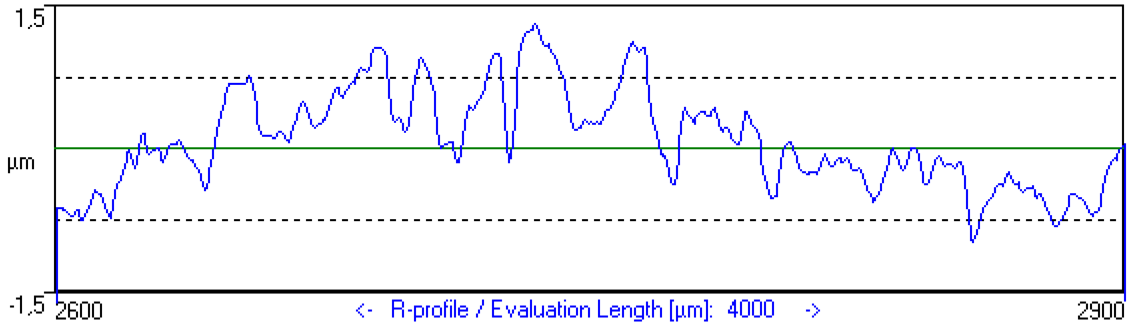


Ra 0,655
Rz 4,522
Rzmax 5,730
RSm 55,623

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator C, Date: 19.4.2010, Workpiece P2 – 1% oil concentration (P0.3/W1)

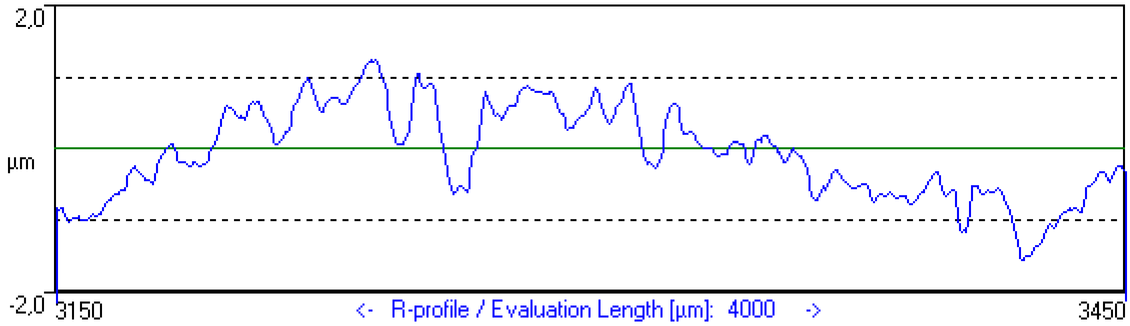
File: B2_1%.dat   Profile no.: 4   Specimenmark: 0393341   14-06-2010



Ra 0,417
Rz 2,662
Rzmax 3,070
RSm 33,594

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: B2_1%.dat   Profile no.: 4   Specimenmark: 0393341   14-06-2010

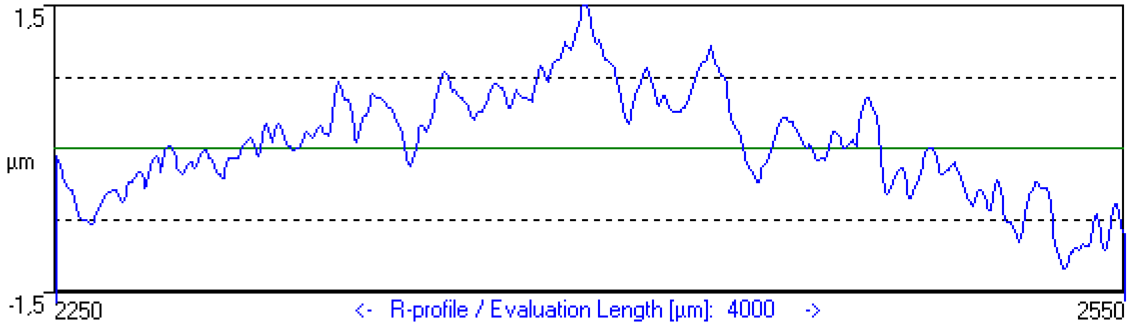


Ra 0,417
Rz 2,662
Rzmax 3,070
RSm 33,594

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator C, Date: 19.4.2010, Workpiece R2 – 1% oil concentration (R0.3/W1)

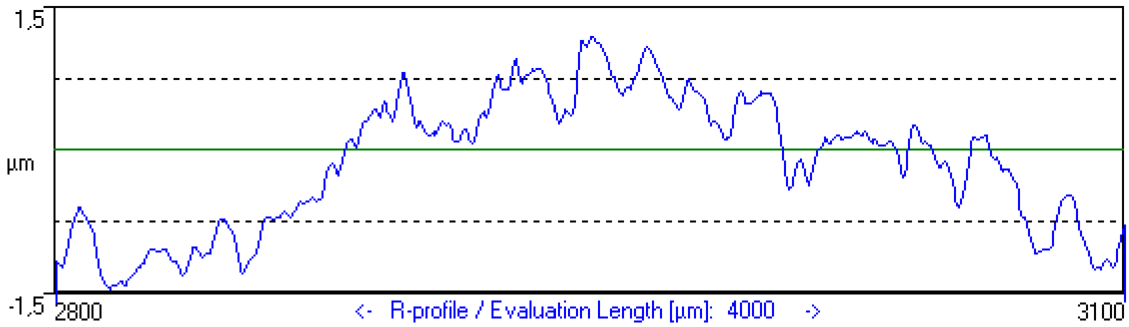
File: R2_1%.dat   Profile no.: 4   Specimenmark: 0393341   14-06-2010



Ra 0,493
Rz 3,054
Rzmax 3,900
RSm 40,527

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: R2_1%.dat   Profile no.: 4   Specimenmark: 0393341   14-06-2010

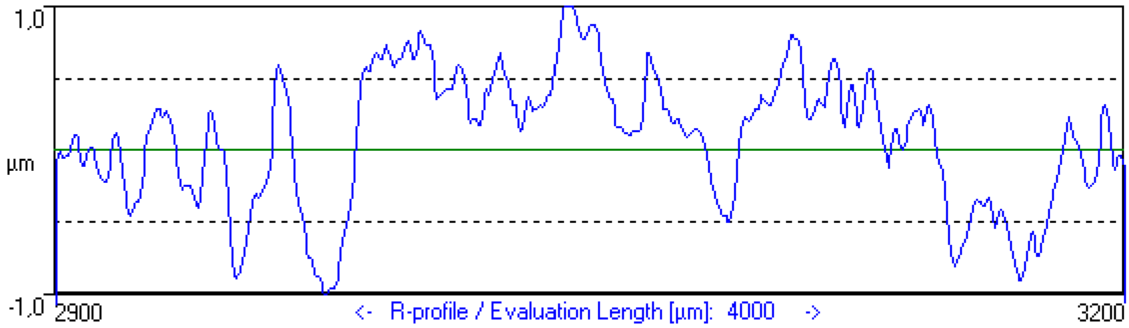


Ra 0,493
Rz 3,054
Rzmax 3,900
RSm 40,527

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator A, Date: 26.4.2010, Workpiece P1 – 1% oil concentration (P0.3/W1)

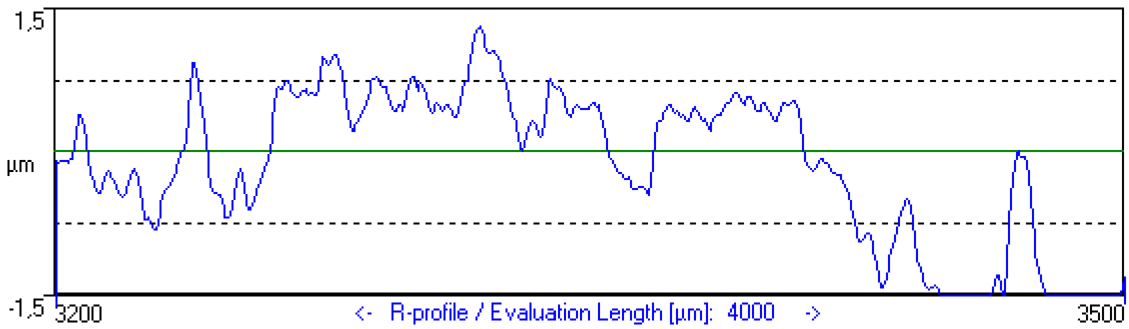
File: P1_1%.dat Profile no.: 2 Specimenmark: 0393341 14-06-2010



Ra 0,371
Rz 2,386
Rzmax 3,450
RSm 29,148

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: P1_1%.dat Profile no.: 2 Specimenmark: 0393341 14-06-2010

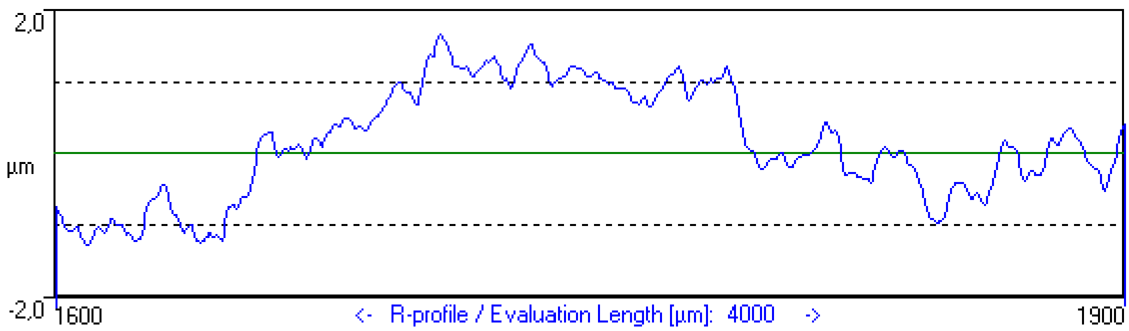


Ra 0,371
Rz 2,386
Rzmax 3,450
RSm 29,148

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator A, Date: 26.4.2010, Workpiece R2 – 1% oil concentration (R0.3/W1)

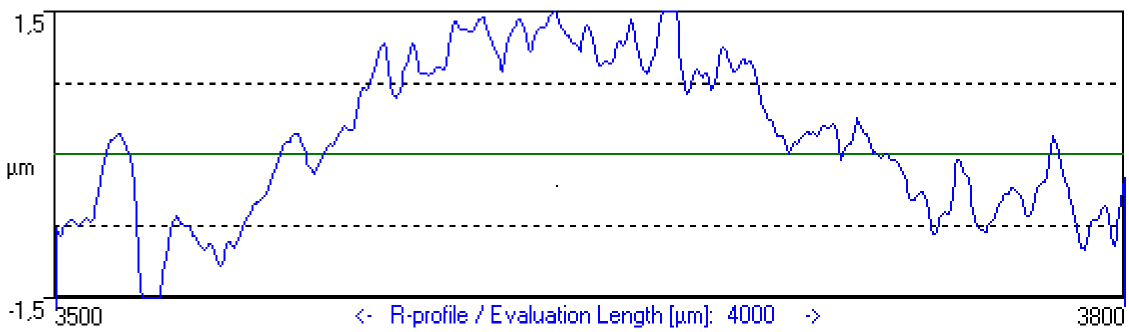
File: R2_1%.dat Profile no.: 2 Specimenmark: 0393341 14-06-2010



Ra 0,577
Rz 3,664
Rzmax 4,370
RSm 42,667

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

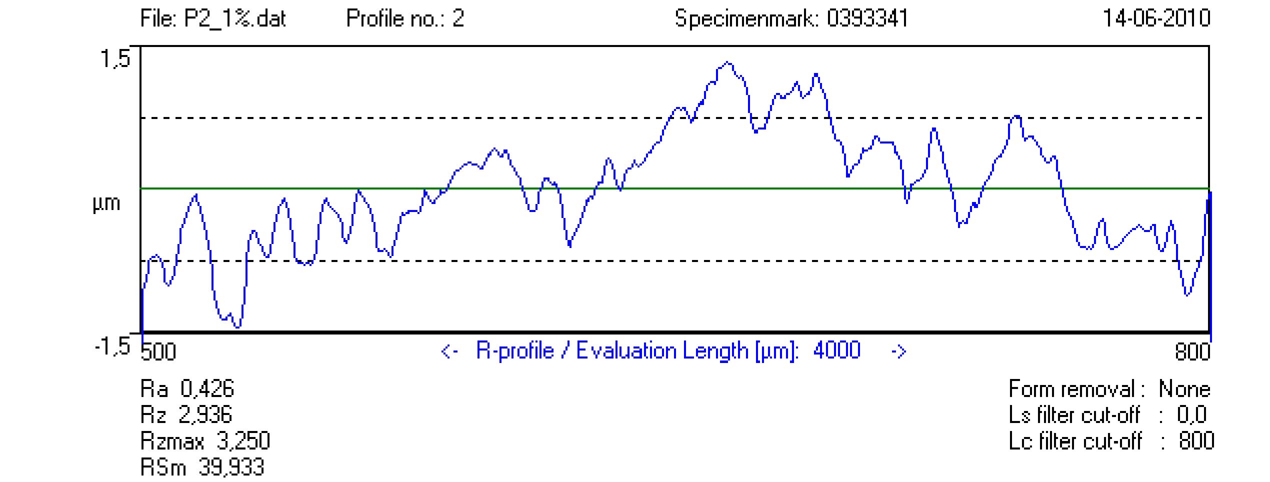
File: R2_1%.dat Profile no.: 2 Specimenmark: 0393341 14-06-2010

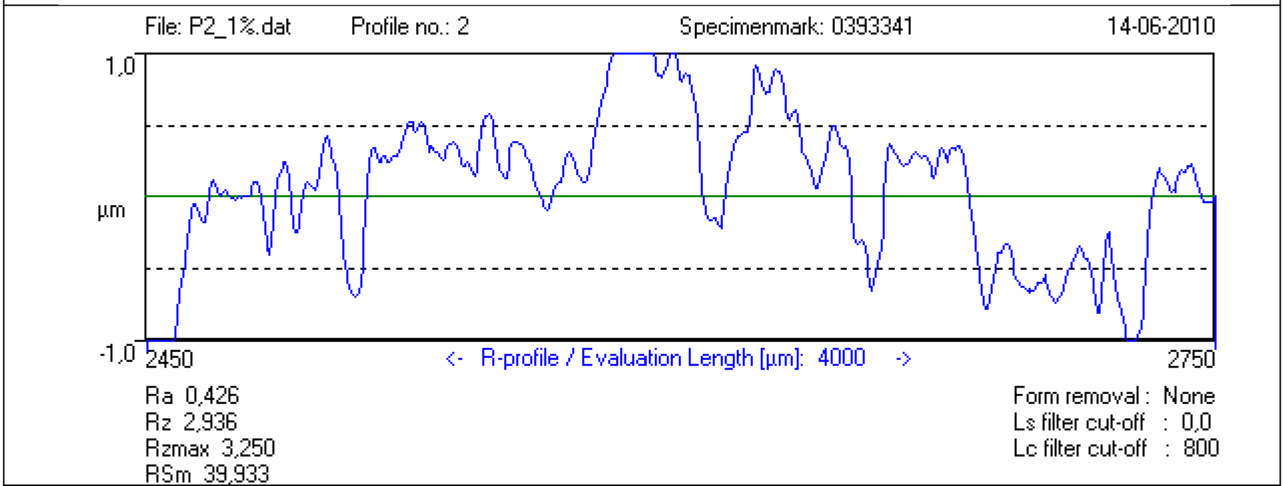


Ra 0,577
Rz 3,664
Rzmax 4,370
RSm 42,667

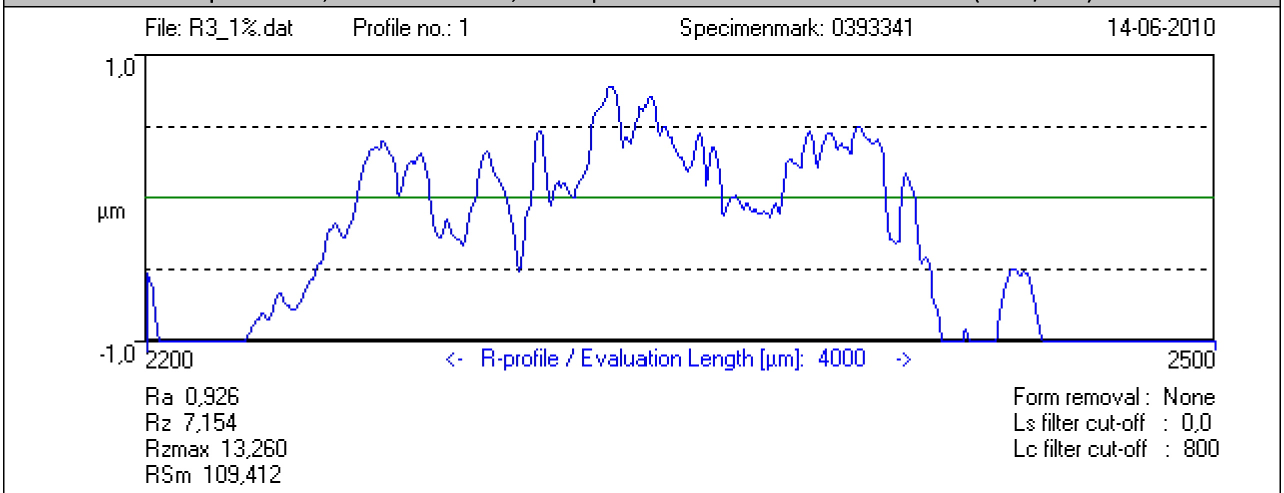
Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

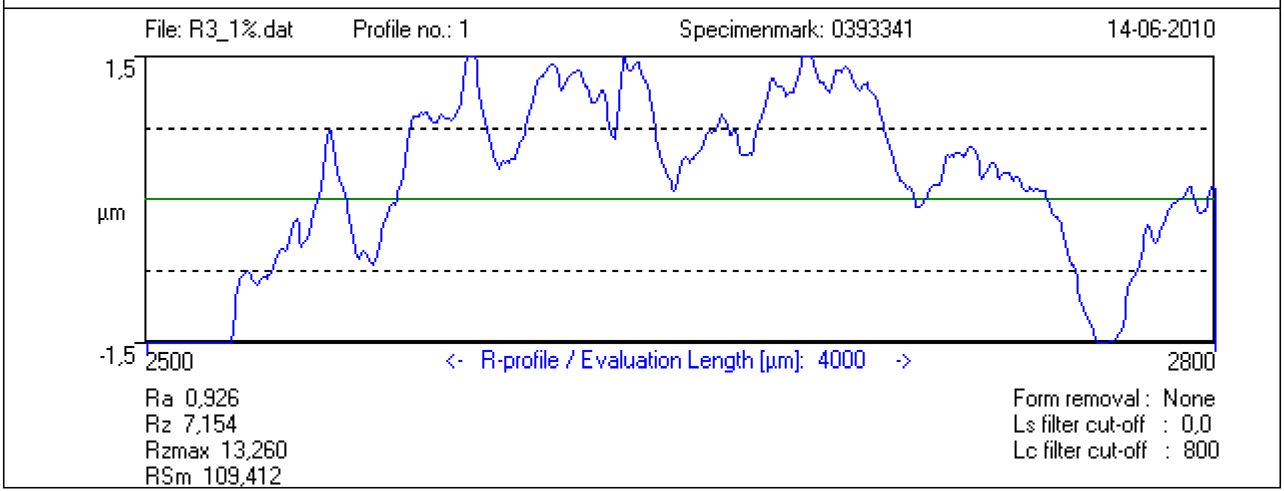
Operator D, Date: 3.5.2010, Workpiece P2 – 1% oil concentration (P0.3/W1)





Operator D, Date: 3.5.2010, Workpiece R3 – 1% oil concentration (R0.3/W1)

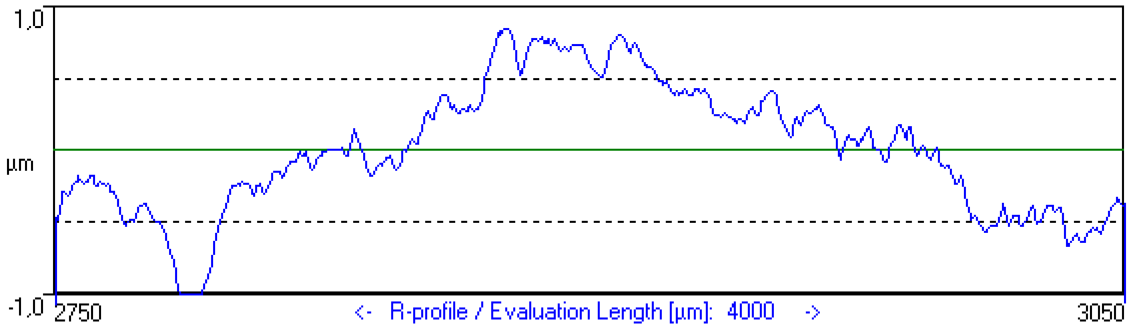




Appendix E2: Surface roughness profiles corresponding to feed marks of a cutting tool – M lubrication

Operator B, Date: 12.4.2010, Workpiece P3 –oil (P0.3/M)

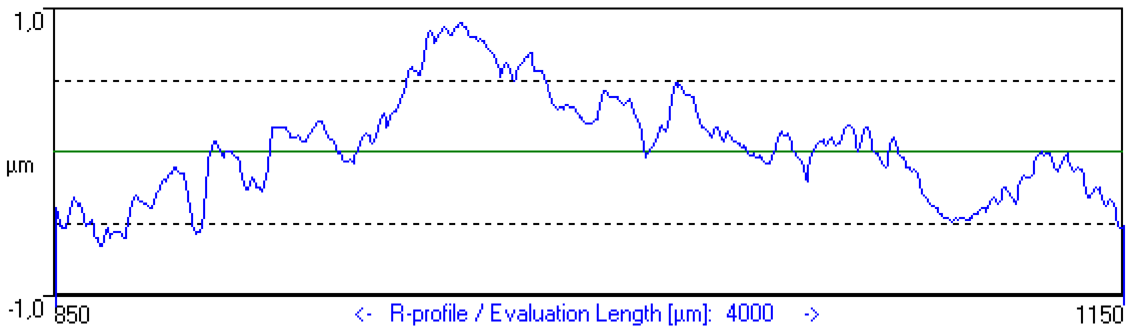
File: P3_oil.dat   Profile no.: 2   Specimenmark: 0393341   14-06-2010



Ra 0,348
Rz 2,446
Rzmax 3,160
RSm 78,202

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: P3_oil.dat   Profile no.: 2   Specimenmark: 0393341   14-06-2010

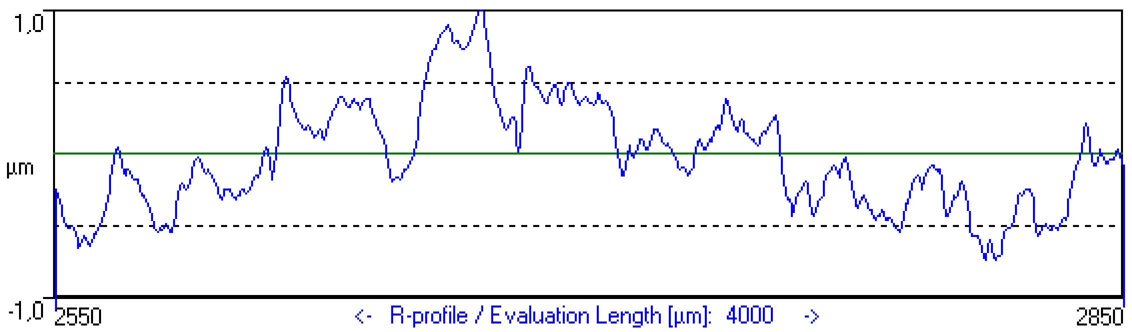


Ra 0,348
Rz 2,446
Rzmax 3,160
RSm 78,202

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator B, Date: 12.4.2010, Workpiece R3 – oil (R0.3/M)

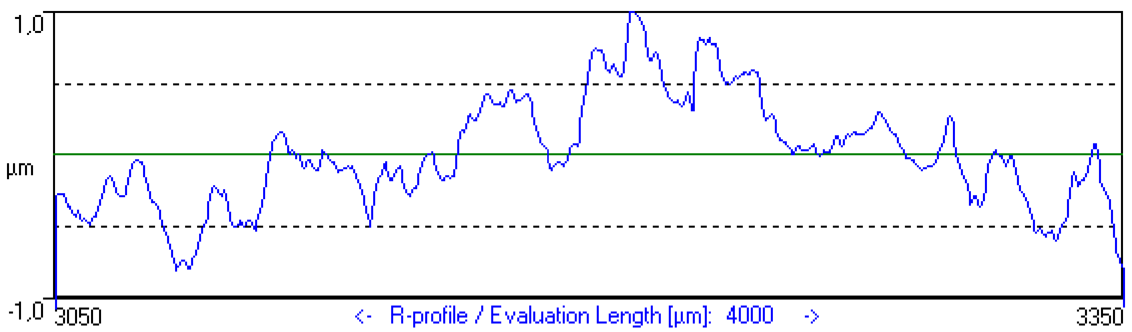
File: R1_oil.dat   Profile no.: 4   Specimenmark: 0393341   14-06-2010



Ra 0,332
Rz 2,300
Rzmax 3,550
RSm 39,475

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: R1_oil.dat   Profile no.: 4   Specimenmark: 0393341   14-06-2010

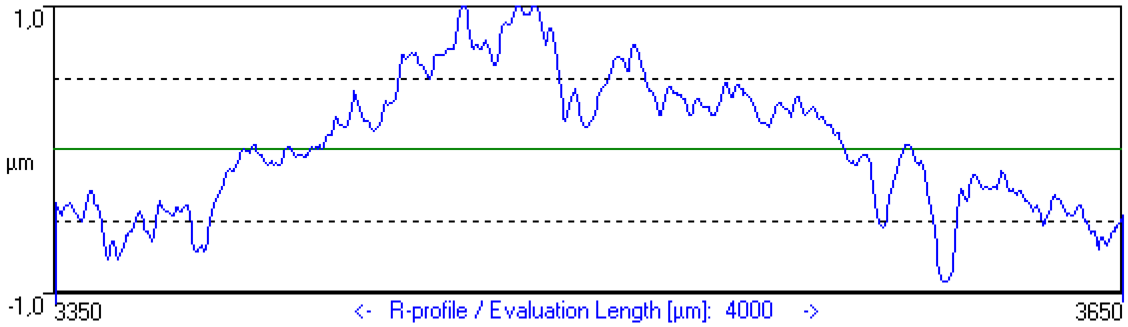


Ra 0,332
Rz 2,300
Rzmax 3,550
RSm 39,475

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator C, Date: 19.4.2010, Workpiece P1 – oil (P0.3/M)

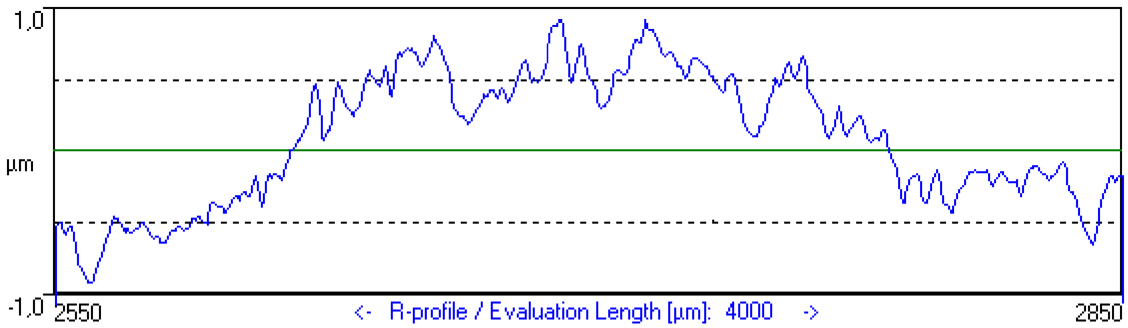
File: B1_OIL.dat Profile no.: 3 Specimenmark: 0393341 14-06-2010



Ra 0,340
Rz 2,190
Rzmax 2,640
RSm 52,826

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: B1_OIL.dat Profile no.: 3 Specimenmark: 0393341 14-06-2010

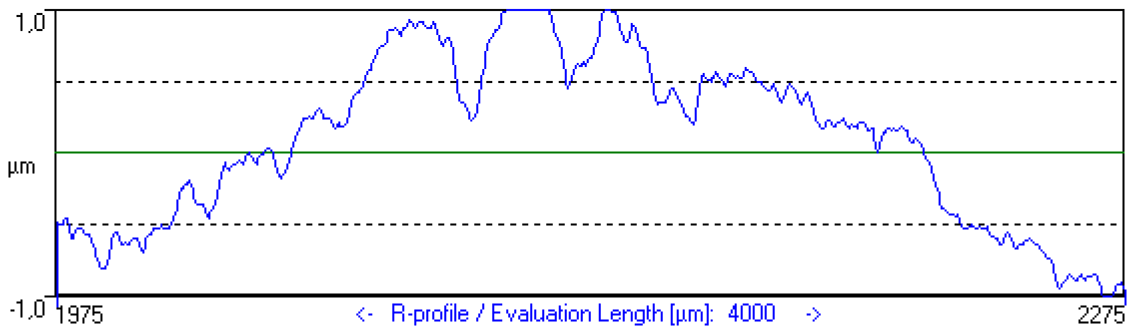


Ra 0,340
Rz 2,190
Rzmax 2,640
RSm 52,826

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator C, Date: 19.4.2010, Workpiece R1 –oil (R0.3/M)

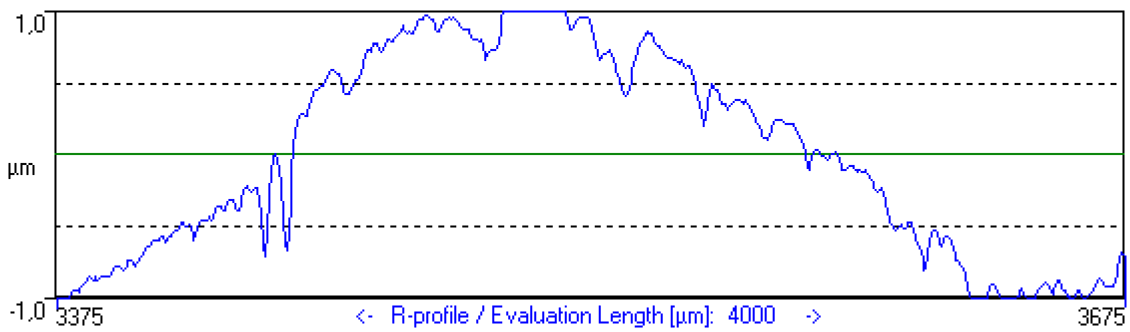
File: R1_OIL.dat Profile no.: 1 Specimenmark: 0393341 14-06-2010



Ra 0,465
Rz 2,778
Rzmax 3,390
RSm 78,480

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: R1_OIL.dat Profile no.: 1 Specimenmark: 0393341 14-06-2010

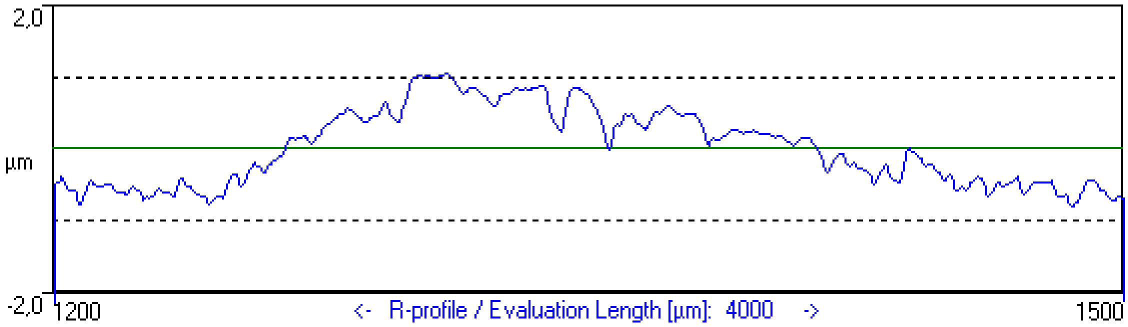


Ra 0,465
Rz 2,778
Rzmax 3,390
RSm 78,480

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator A, Date: 26.4.2010, Workpiece P3 – oil (P0.3/M)

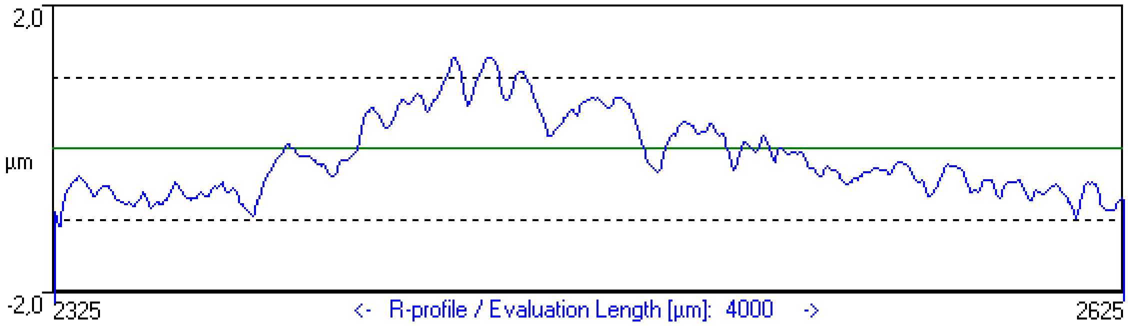
File: P3_100%.dat   Profile no.: 4   Specimenmark: 0393341   14-06-2010



Ra 0,486
Rz 2,826
Rzmax 3,990
RSm 77,221

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: P3_100%.dat   Profile no.: 4   Specimenmark: 0393341   14-06-2010

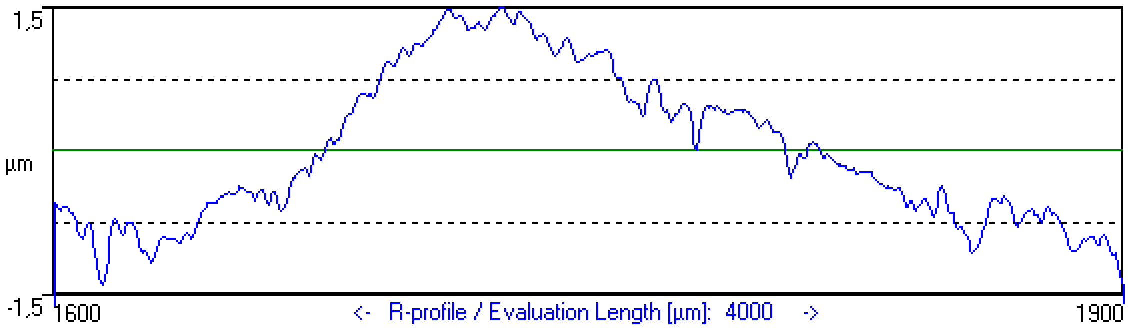


Ra 0,486
Rz 2,826
Rzmax 3,990
RSm 77,221

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator A, Date: 26.4.2010, Workpiece R1 – oil (R0.3/M)

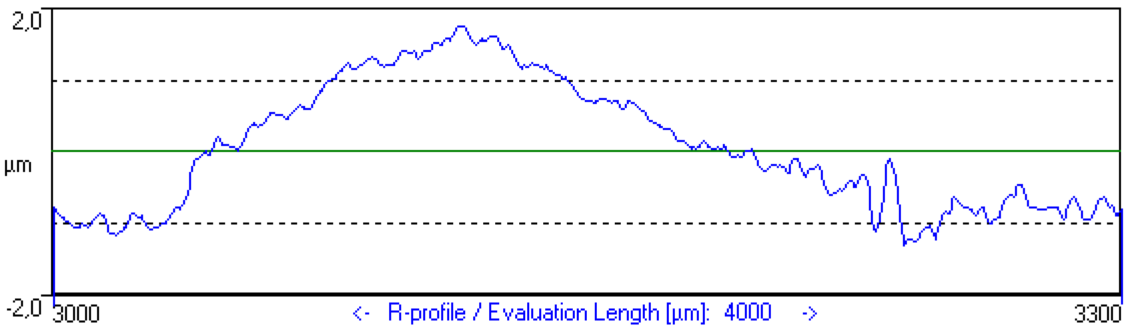
File: R1_100%.dat   Profile no.: 1   Specimenmark: 0393341   14-06-2010



Ra 0,644
Rz 3,614
Rzmax 4,540
RSm 128,100

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: R1_100%.dat   Profile no.: 1   Specimenmark: 0393341   14-06-2010

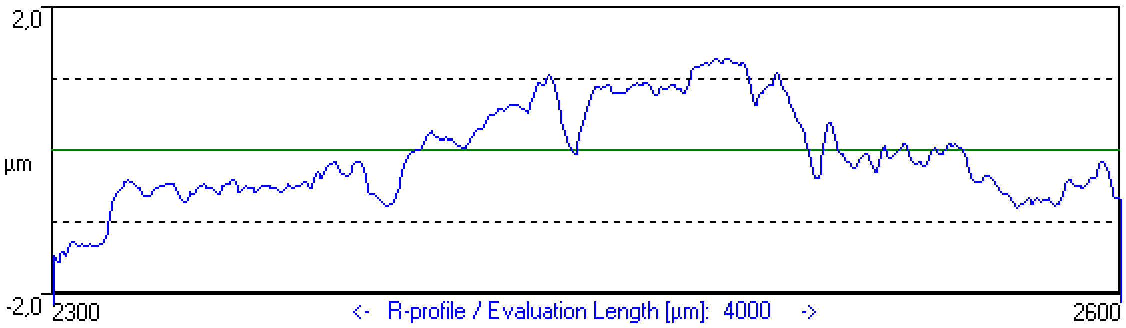


Ra 0,644
Rz 3,614
Rzmax 4,540
RSm 128,100

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator D, Date: 3.5.2010, Workpiece P1 – 1% oil (P0.3/M)

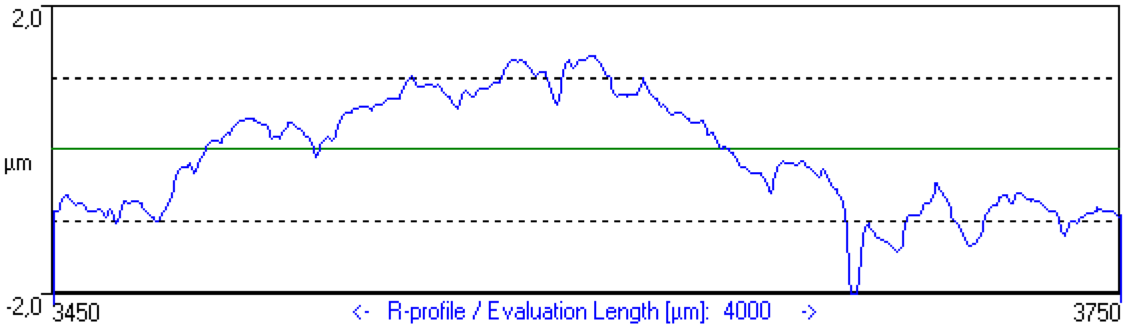
File: P1_100%.dat Profile no.: 1 Specimenmark: 0393341 14-06-2010



Ra 0,537
Rz 3,420
Rzmax 4,750
RSm 60,024

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: P1_100%.dat Profile no.: 1 Specimenmark: 0393341 14-06-2010

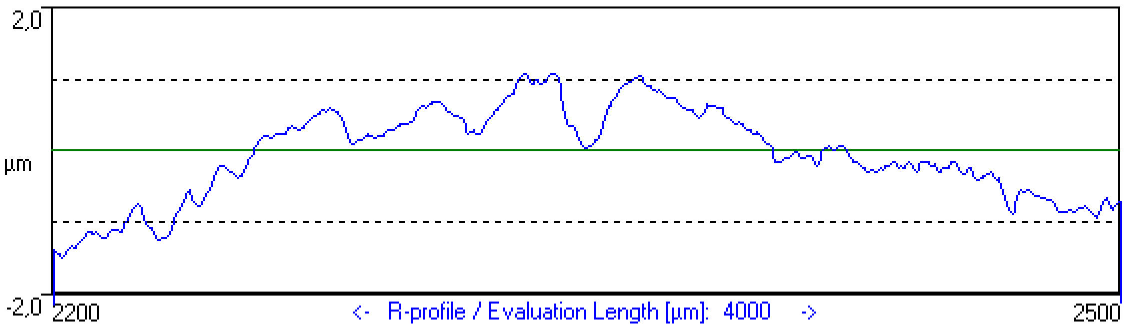


Ra 0,537
Rz 3,420
Rzmax 4,750
RSm 60,024

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator D, Date: 3.5.2010, Workpiece R1 – oil (R0.3/M)

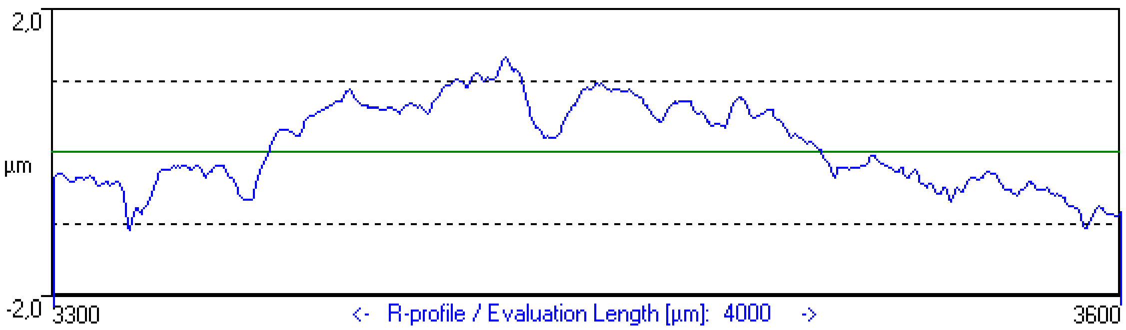
File: R1_100%.dat Profile no.: 1 Specimenmark: 0393341 14-06-2010



Ra 0,472
Rz 2,708
Rzmax 3,410
RSm 82,223

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: R1_100%.dat Profile no.: 1 Specimenmark: 0393341 14-06-2010



Ra 0,472
Rz 2,708
Rzmax 3,410
RSm 82,223

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Appendix F

Measurements on the 3D optical microscope

Appendix F contains profiles of 3D surface profiles. The instrument was a 3D optical microscope InfiniteFocus, Alicona.

Table F.1: Workpieces measured.

Group	Date	WP indication	Lubrication	Code
C	19.4.2010	P2	W1	P/W1
C	19.4.2010	R2	W1	R/W1
C	19.4.2010	P1	W2	P/W2
C	19.4.2010	R3	W2	R/W2
C	19.4.2010	P1	M	P/M
C	19.4.2010	R1	M	R/M
F	22.6.2010	P2	N	P0.3/N
G	22.6.2010	P2	N	P0.2/N

Numbers 1, 2 in the table starting on the following page correspond to a following:

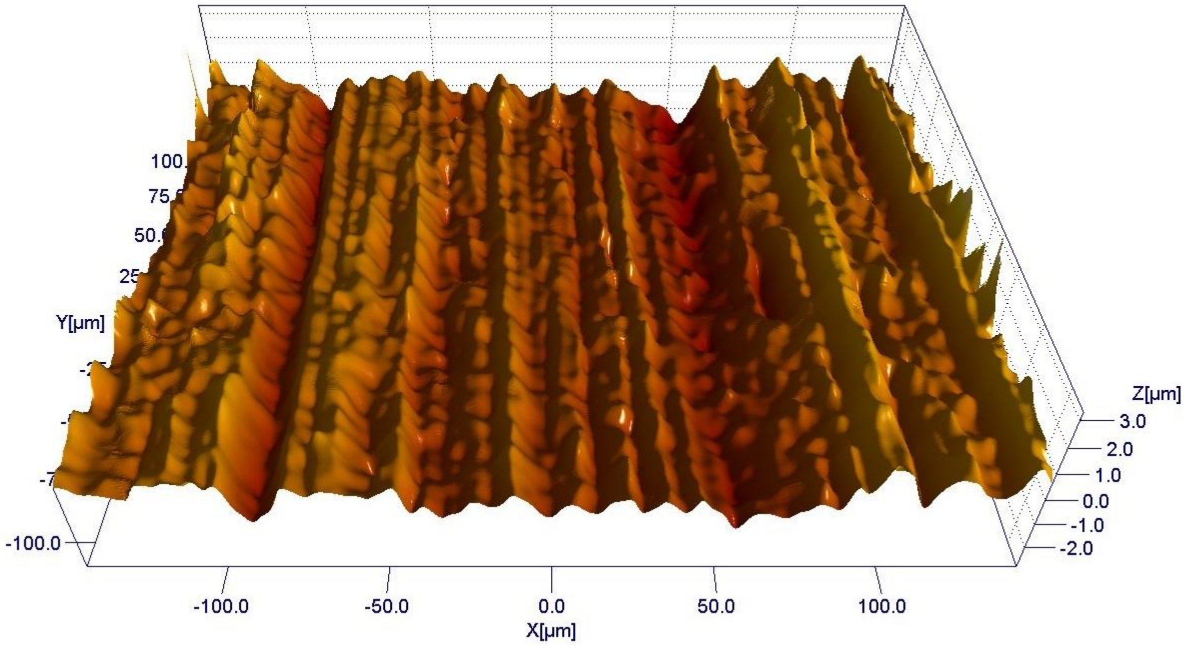
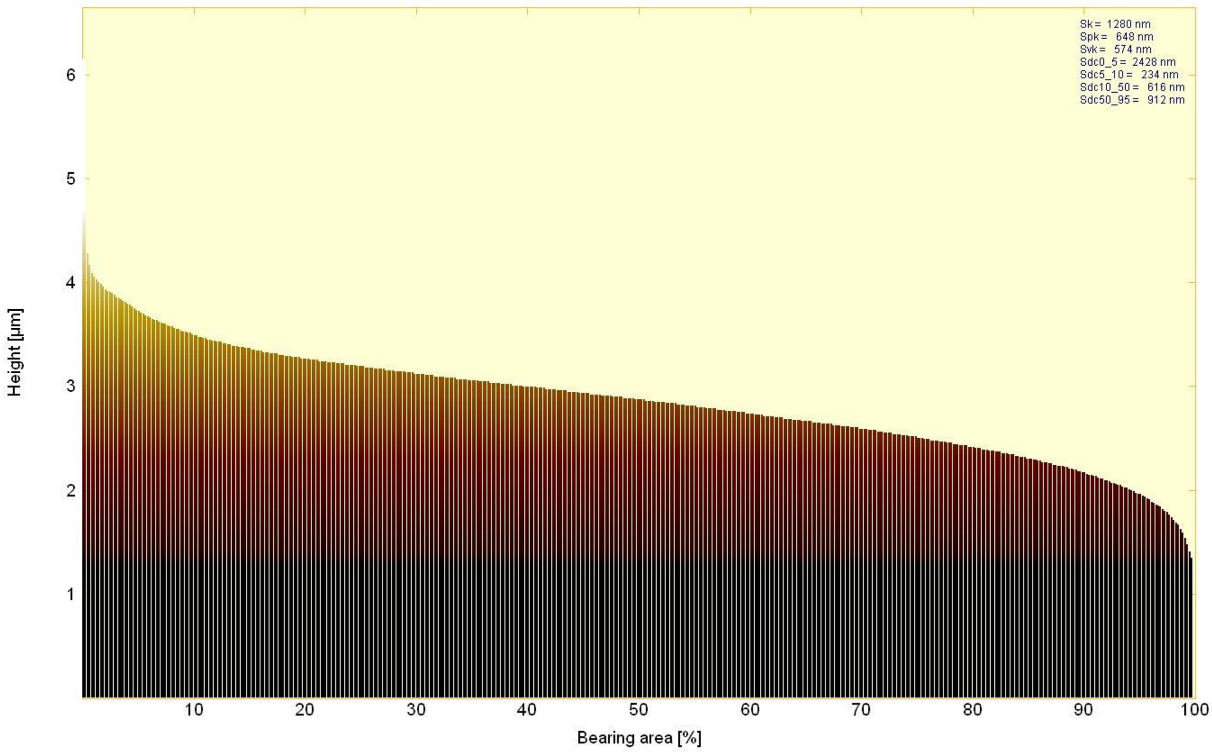
- 1 - 3D view
- 2 - bearing ratio curve

The measured area was 287 x 218 μm. Measuring strategy is in more details explained in Section 2.3.3.

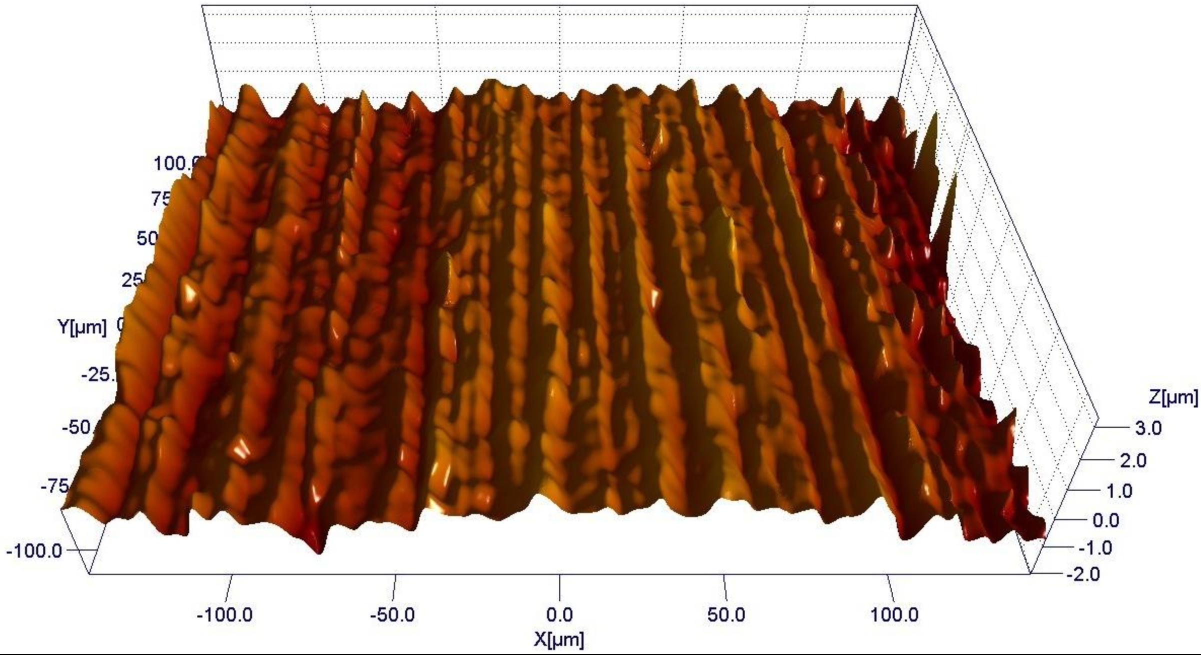
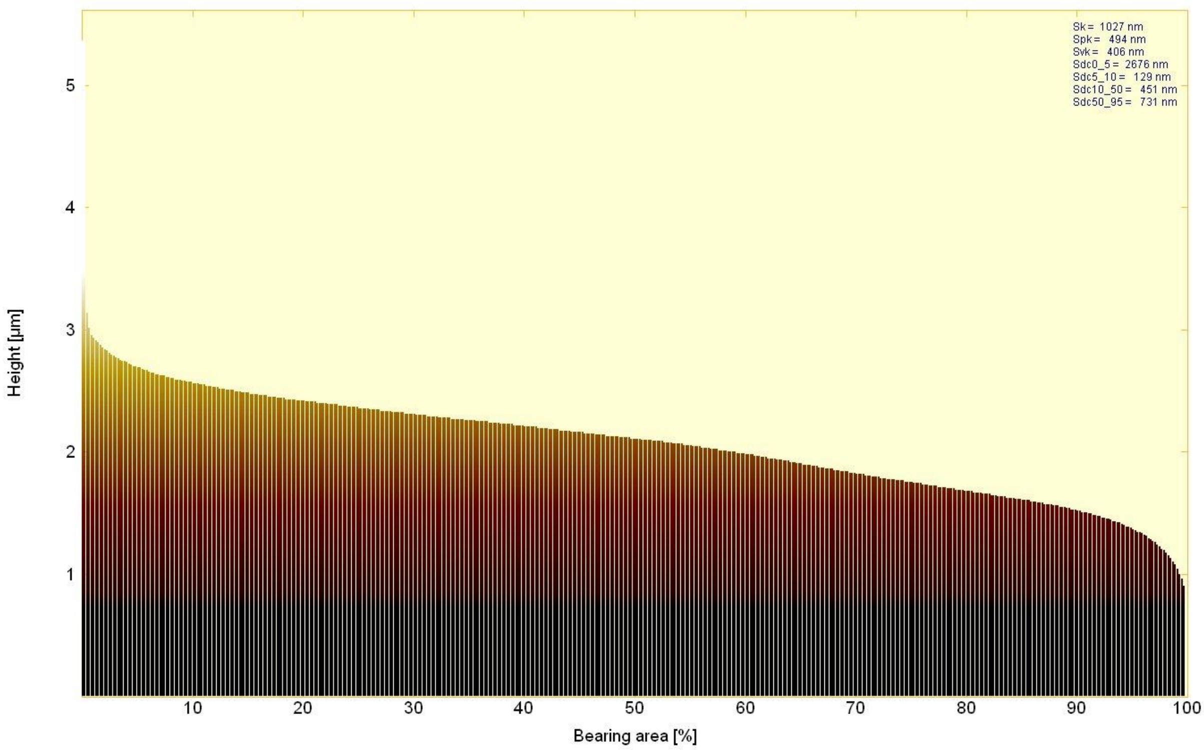
P: Low speed, 4.5 m/min
R: High speed, 10.2 m/min

Feed, 0.3 mm/rev (operators C and F)
Feed, 0.2 mm/rev (operator G)

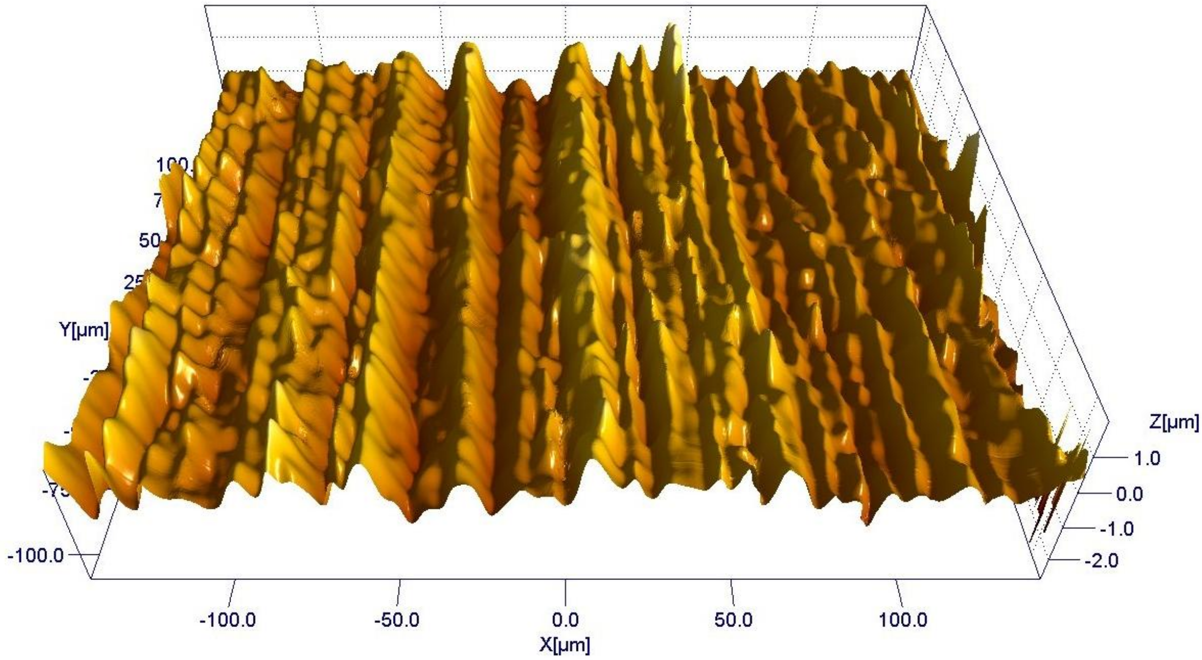
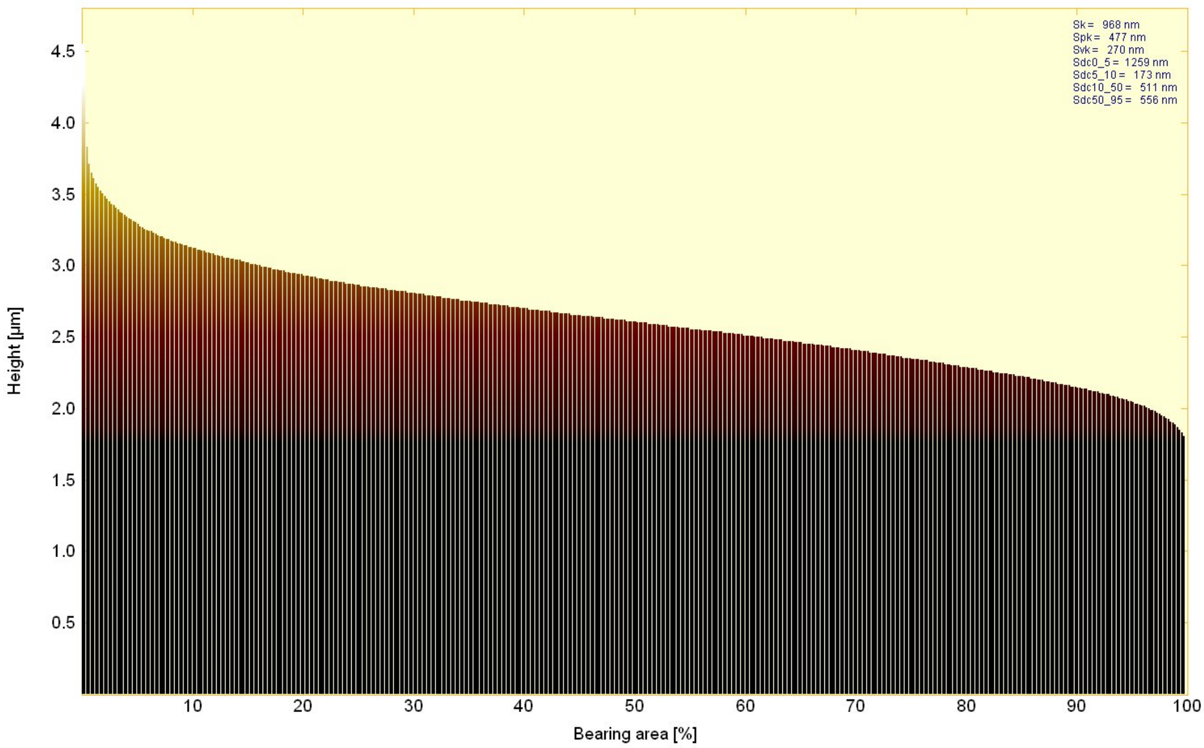
P/W1

<table>
<tr><th></th><th>Group C, Date: 19.4.2010, Workpiece P2 – 1% oil concentration (P0.3/W1)</th></tr>
<tr><td>1</td><td>
</td></tr>
<tr><td>2</td><td>
</td></tr>
</table>

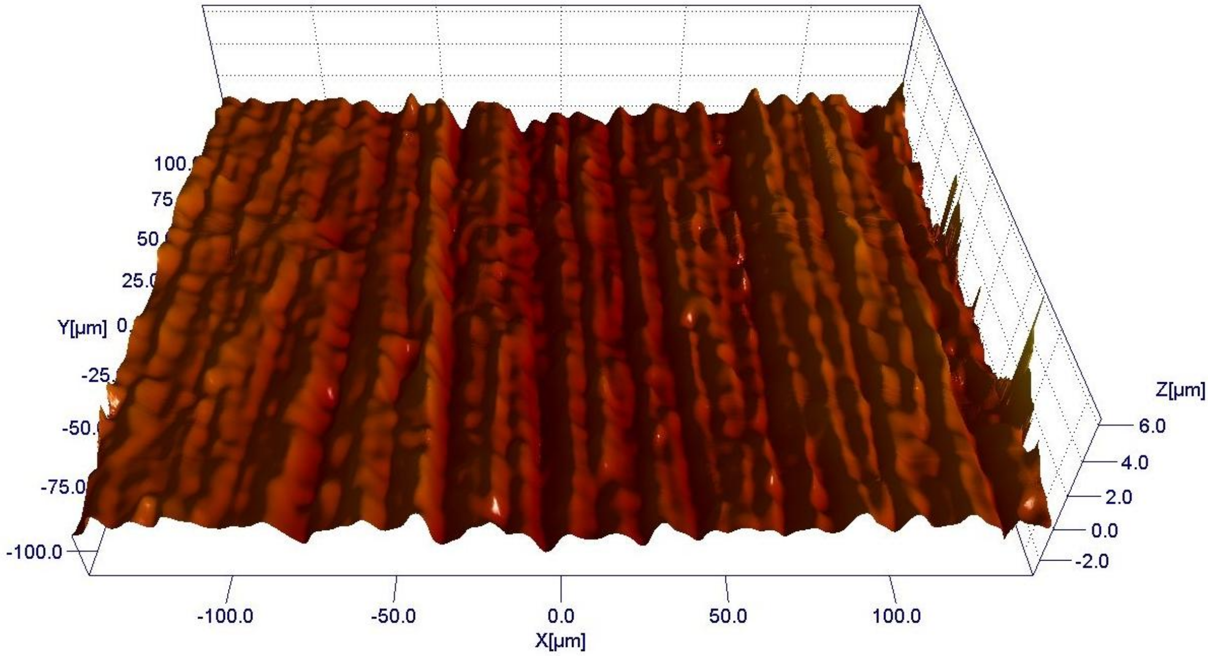
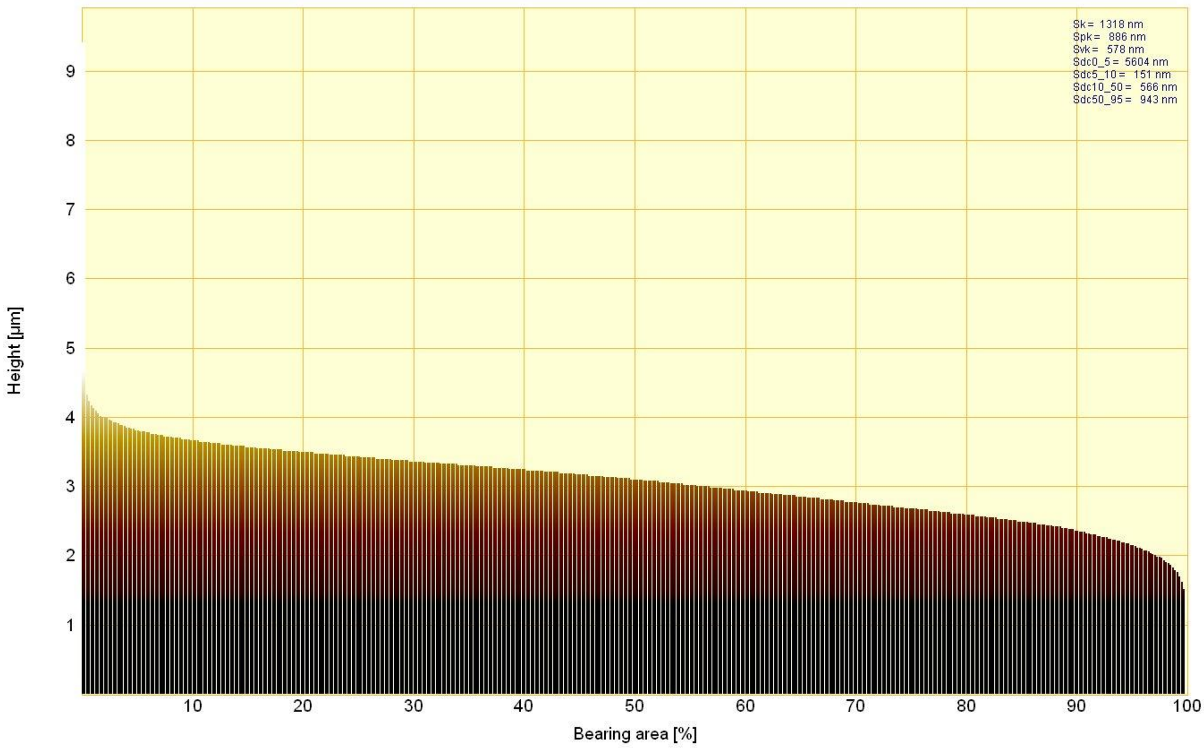
R/W1

	Group C, Date: 19.4.2010, Workpiece R2 – 1% oil concentration (R0.3/W2)
1	
2	

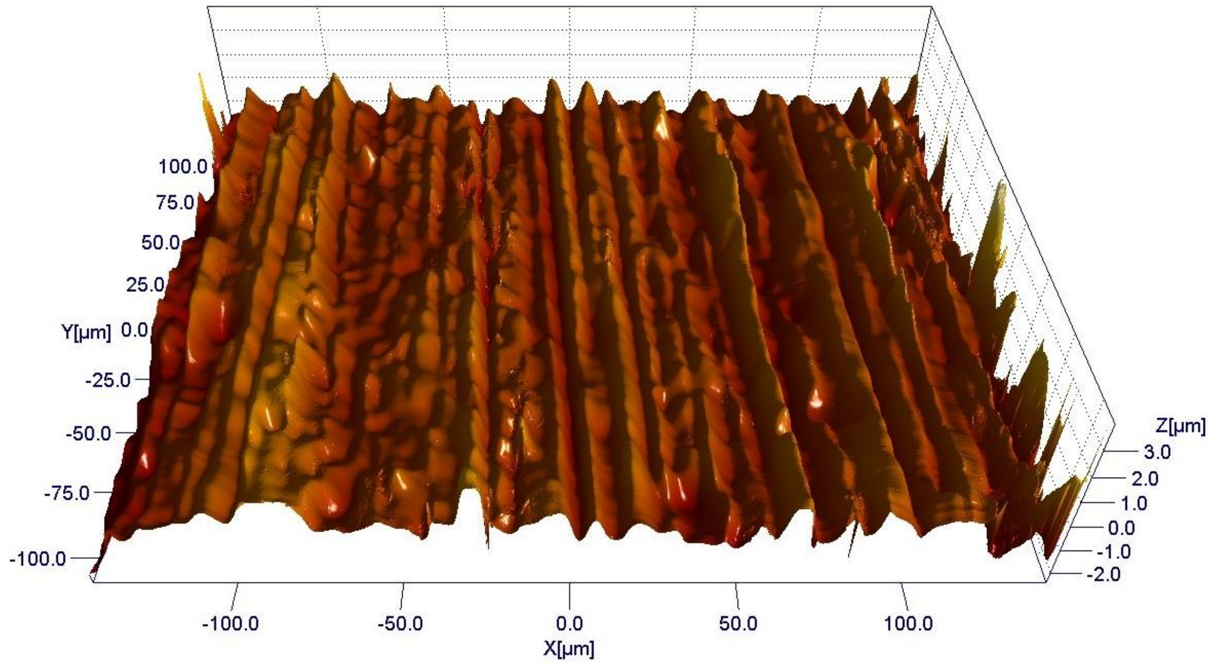
P/W2

	Group C, Date: 19.4.2010, Workpiece P1 – 10% oil concentration (P0.3/W2)
1	
2	

R/W2

<table>
<tr><th></th><th>Group C, Date: 19.4.2010, Workpiece R3 – 10% oil concentration (R0.3/W2)</th></tr>
<tr><td>1</td><td>
</td></tr>
<tr><td>2</td><td>
</td></tr>
</table>

P/M

<table>
<tr><th></th><th>Group C, Date: 19.4.2010, Workpiece P1 –mineral oil (P0.3/M)</th></tr>
<tr><td>1</td><td>
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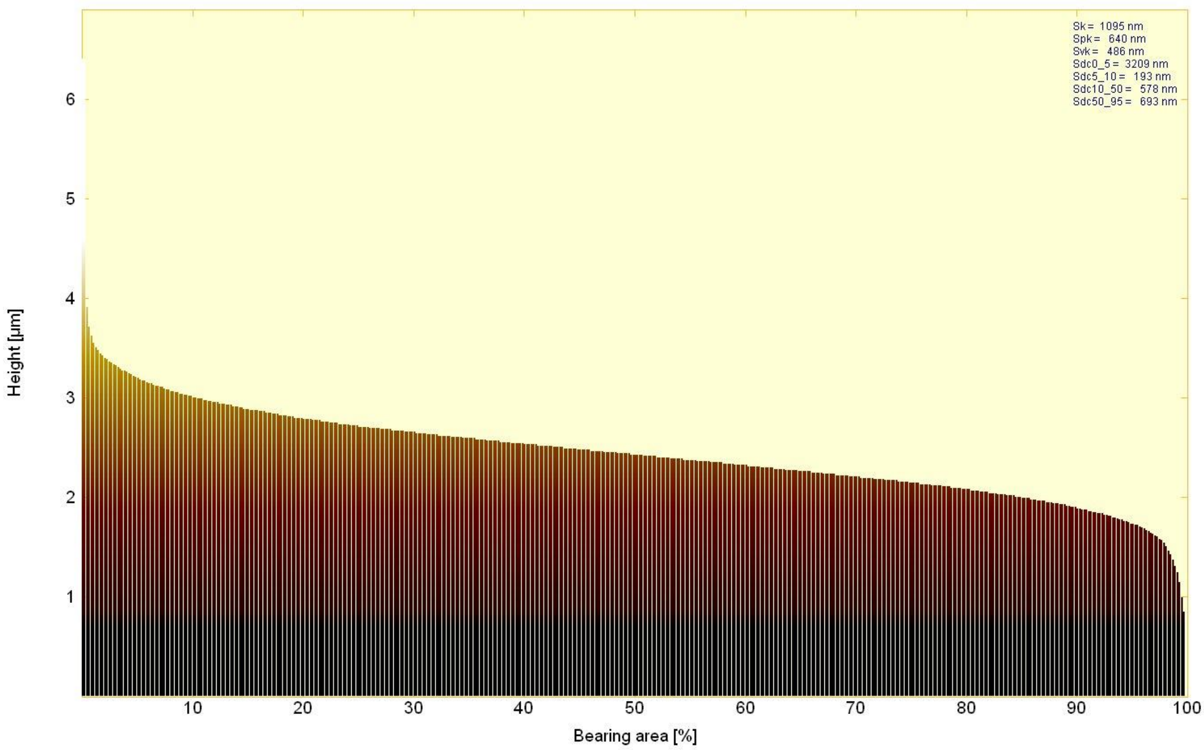
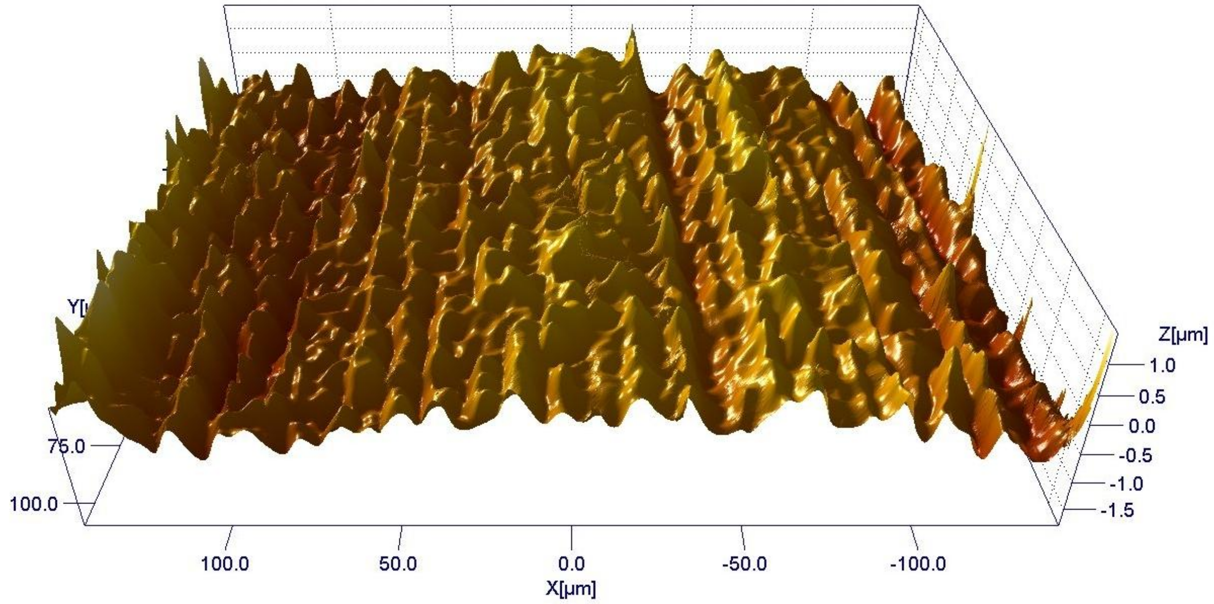
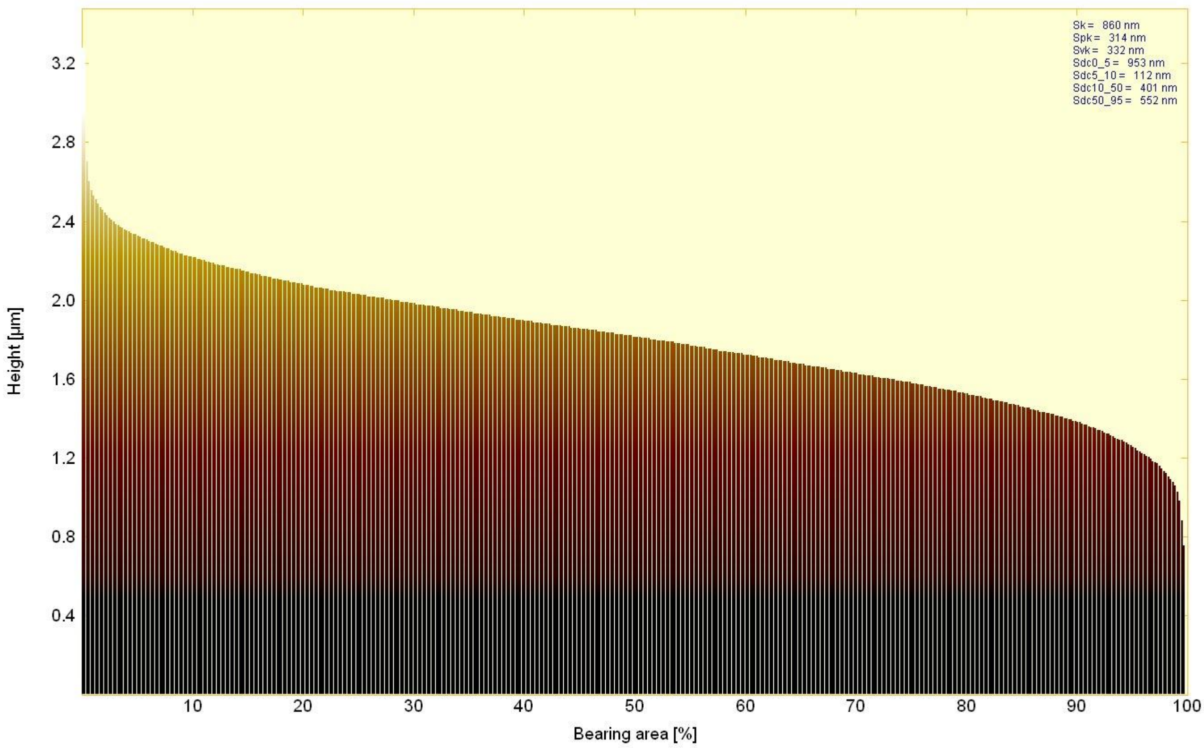
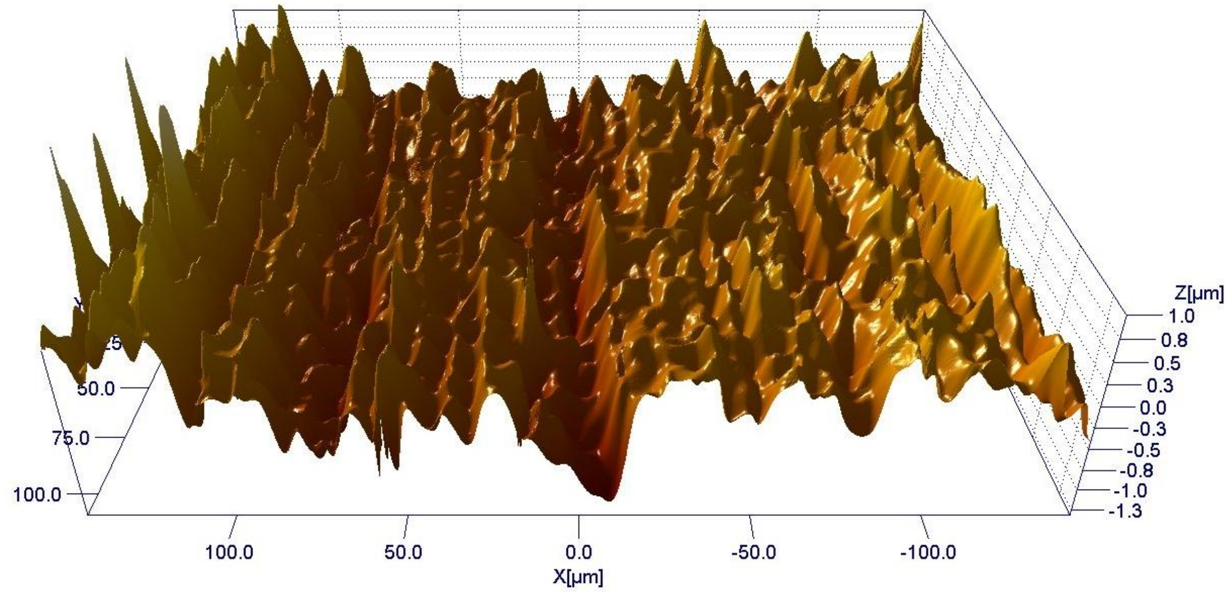
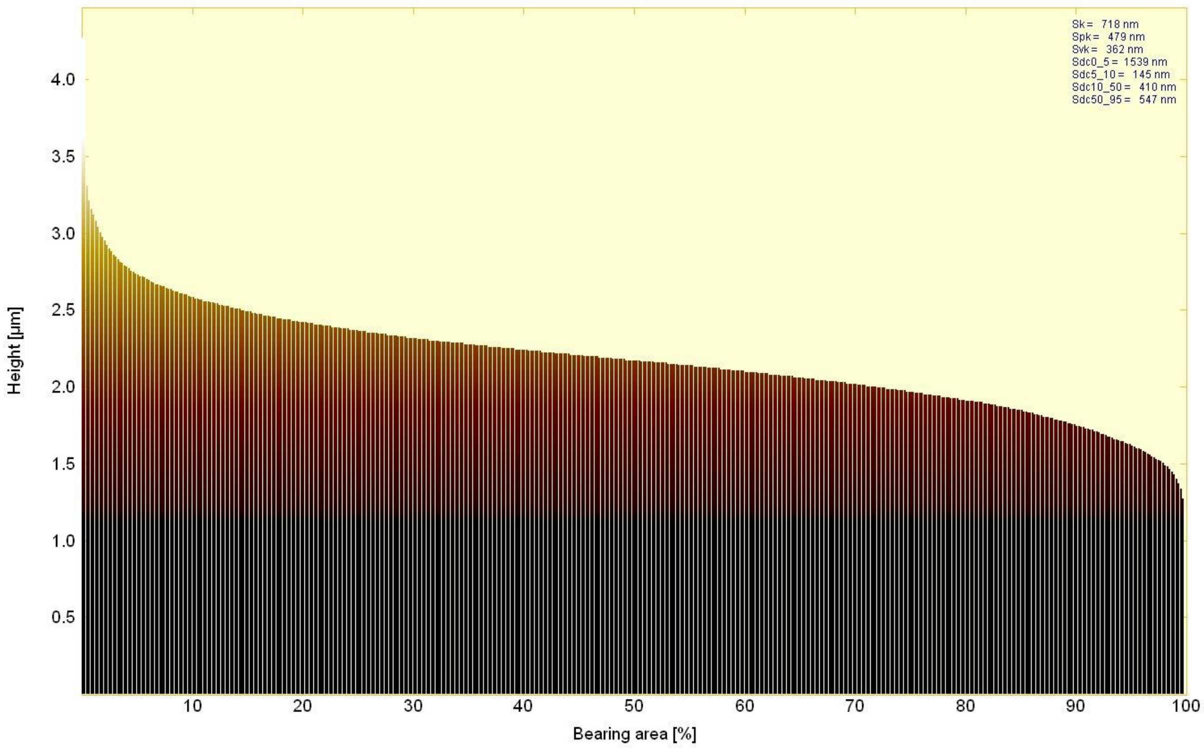
<tr><td>2</td><td>
</td></tr>
</table>

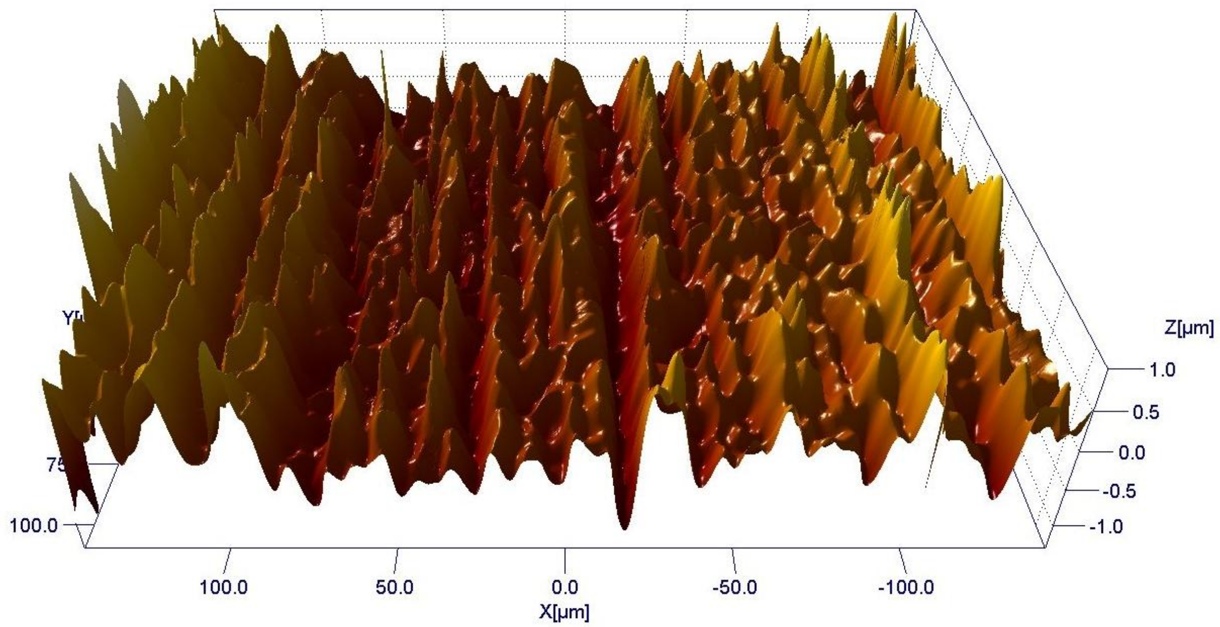
R/M

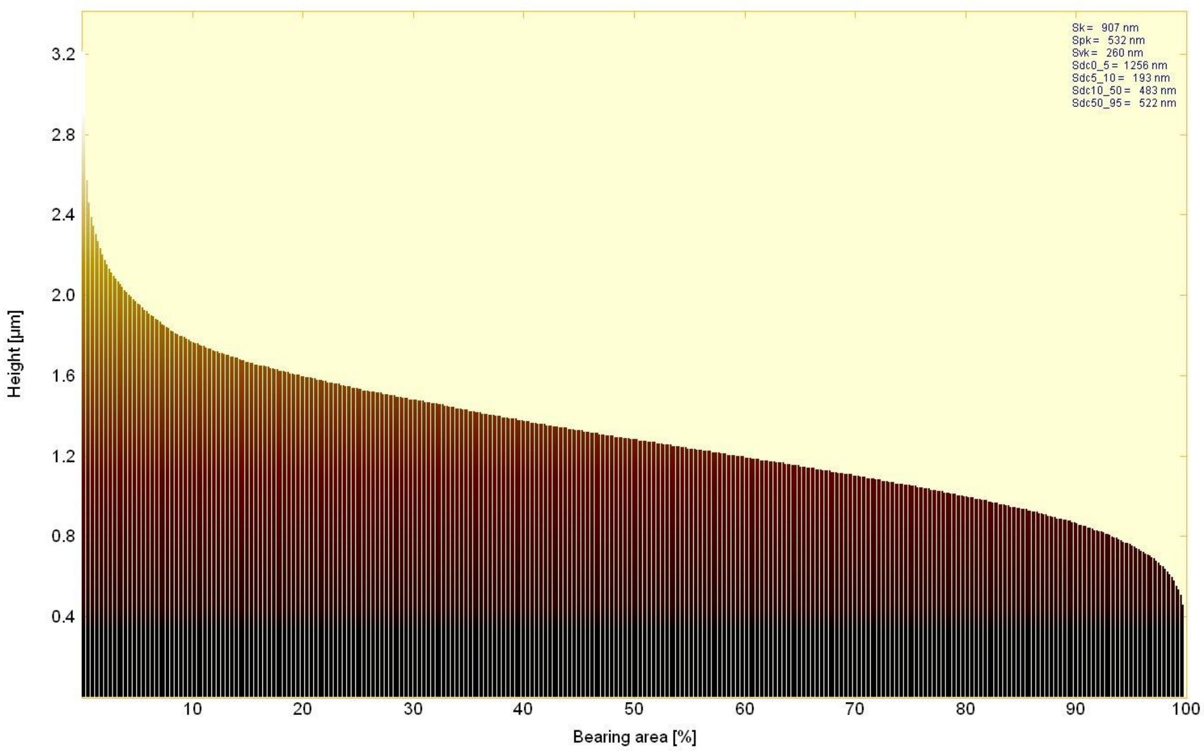
	Group C, Date: 19.4.2010, Workpiece R1 –mineral oil (R0.3/M)
1	
2	

P0.3/N

<table>
<tr><th></th><th>Group C, Date: 19.4.2010, Workpiece P2 – neat oil (P0.3/N)</th></tr>
<tr><td>1</td><td>
</td></tr>
<tr><td>2</td><td>
</td></tr>
</table>

P0.2/N

<table>
<tr><th></th><th>Group C, Date: 19.4.2010, Workpiece P2 – neat oil (P0.2/N)</th></tr>
<tr><td>1</td><td>


</td></tr>
<tr><td>2</td><td>


</td></tr>
</table>

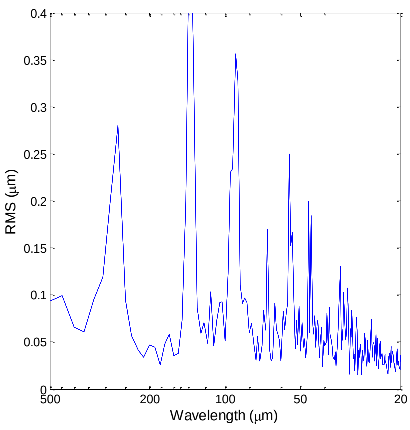
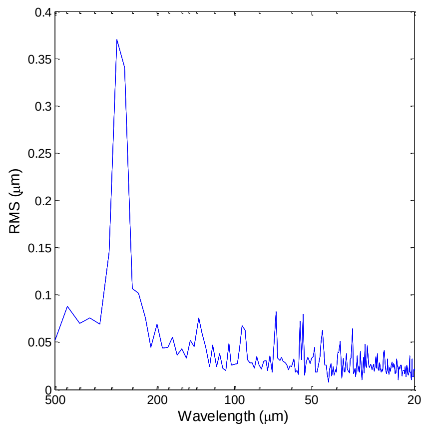
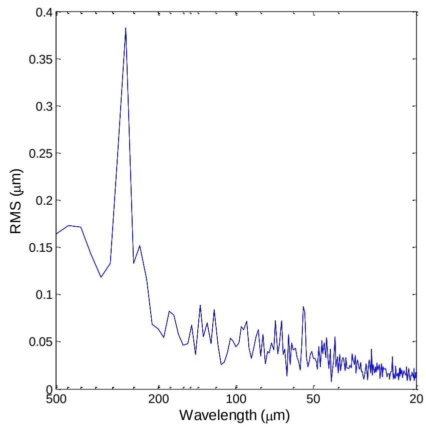
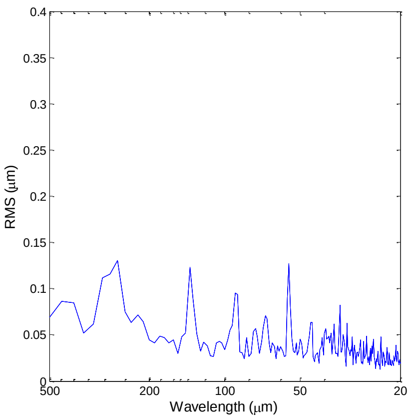
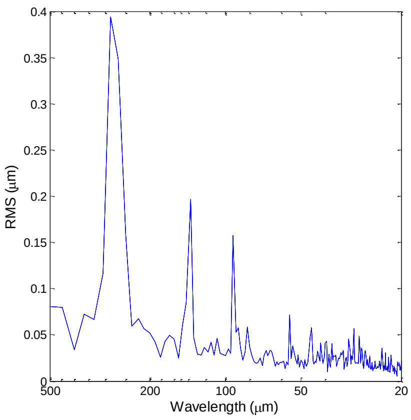
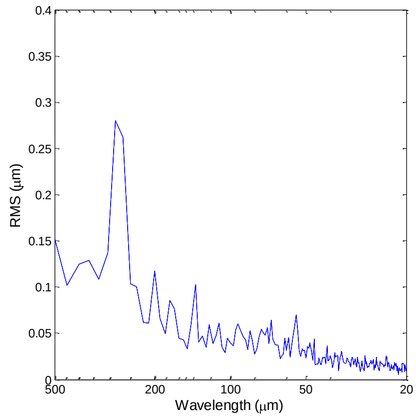
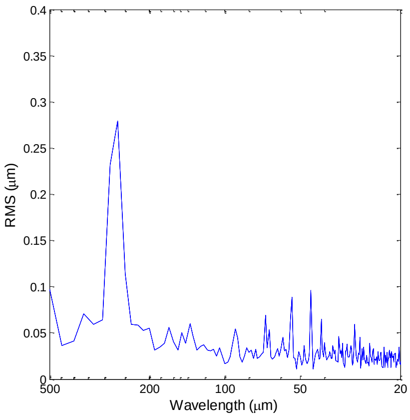
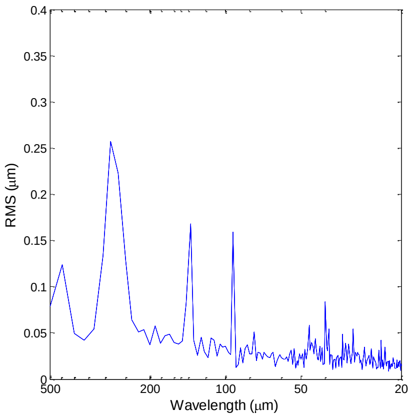
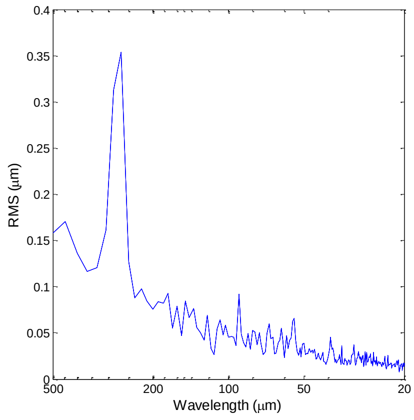
Appendix G

Frequency analysis

Appendix G contains frequency analysis profiles of reamed holes from all the operators (i.e. E, A, B, C, D, F, G). Graphs are plotted in linear and logarithmic scales. Each graph represents an average of four profiles which are taken around the hole circumference.

Appendix G1: Frequency analysis

Operator E: 23/03-2010

<table>
<tr><th colspan="4">23.3. Operator E – low speed, feed 0.3mm/rev – linear scale</th></tr>
<tr><th></th><th>P_1%</th><th>P_10%</th><th>P_oil</th></tr>
<tr><td>Wp1</td><td></td><td></td><td></td></tr>
<tr><td>Wp2</td><td></td><td></td><td></td></tr>
<tr><td>Wp3</td><td></td><td></td><td></td></tr>
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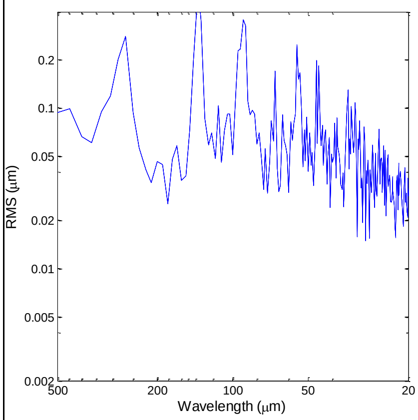
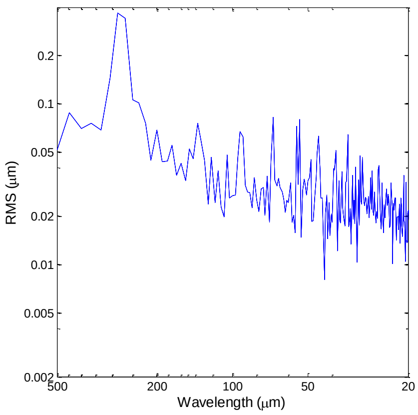
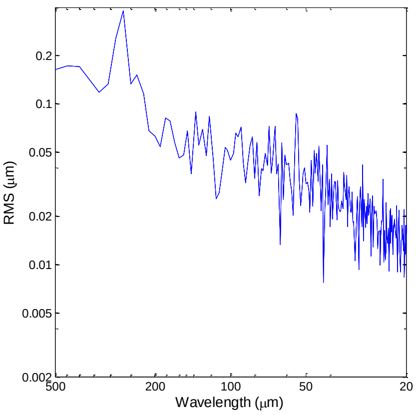
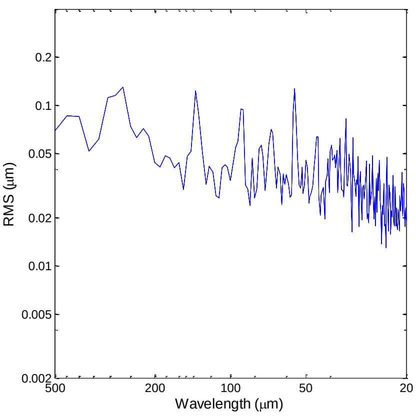
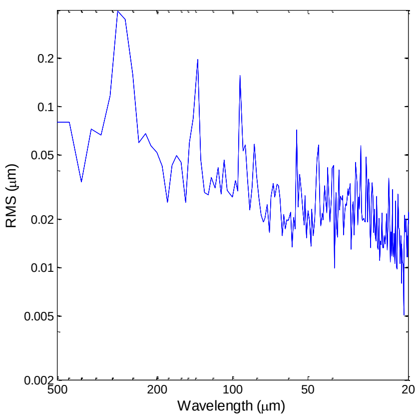
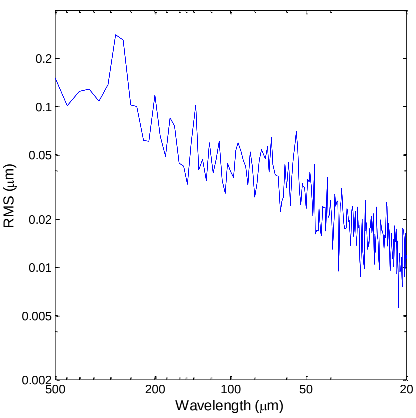
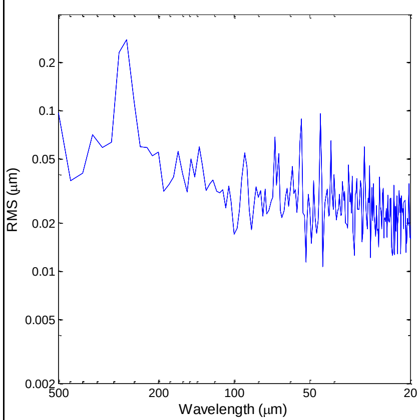
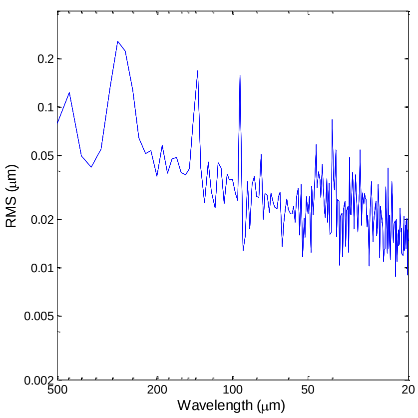
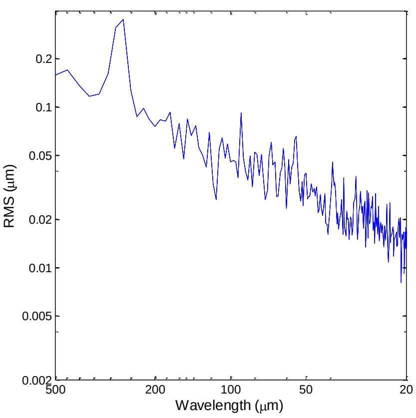
<tr><td>Wp1</td><td></td><td></td><td></td></tr>
<tr><td>Wp2</td><td></td><td></td><td></td></tr>
<tr><td>Wp3</td><td></td><td></td><td></td></tr>
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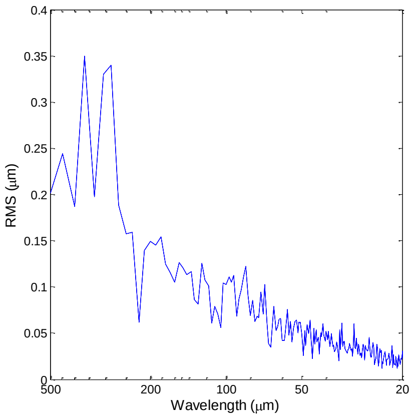
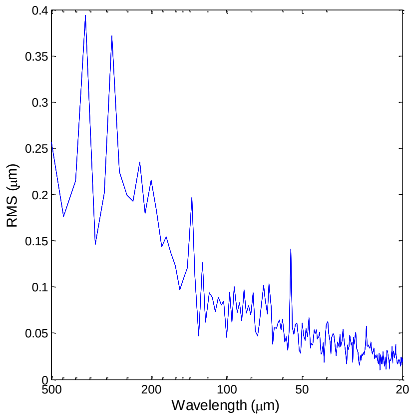
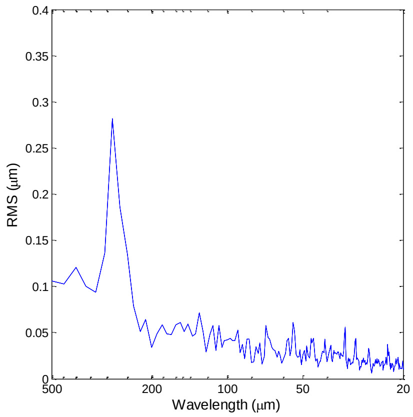
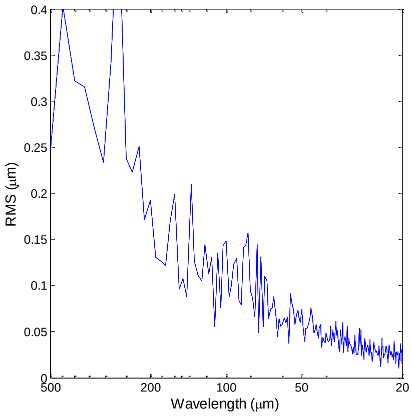
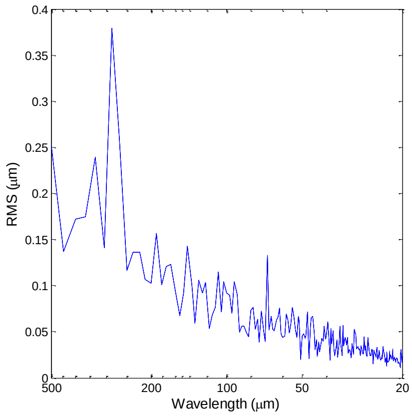
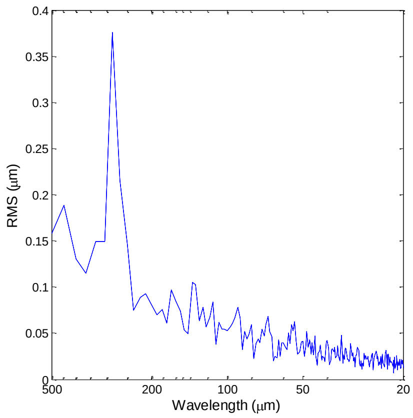
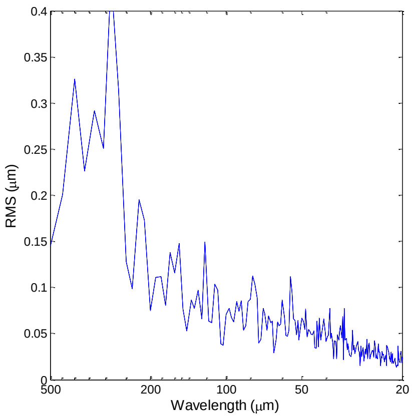
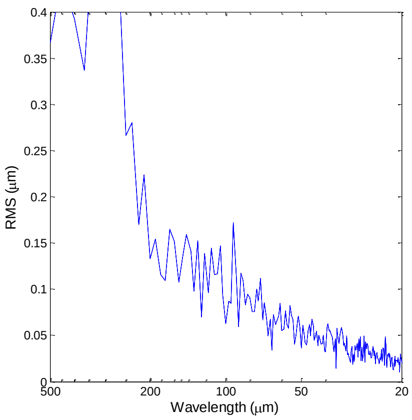
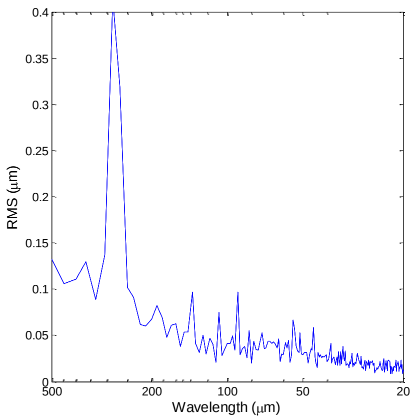
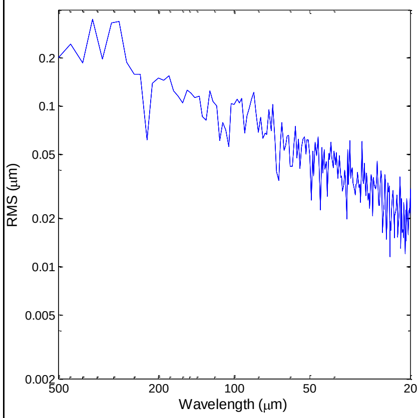
23.3. Operator E – high speed, feed 0.3mm/rev –linear scale			
	R_1%	R_10%	R_oil
Wp1			
Wp2			
Wp3			

<table>
<tr><th colspan="4">23.3. Operator E – high speed, feed 0.3mm/rev – log scale</th></tr>
<tr><th></th><th>R_1%</th><th>R_10%</th><th>R_oil</th></tr>
<tr><td>Wp1</td>
<td>
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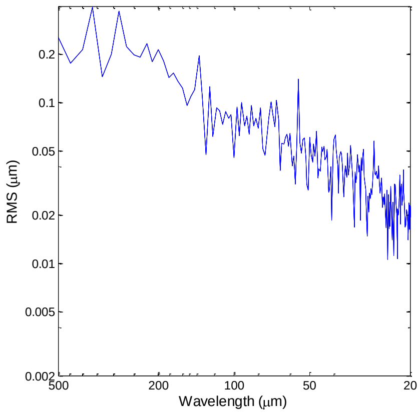
<td>
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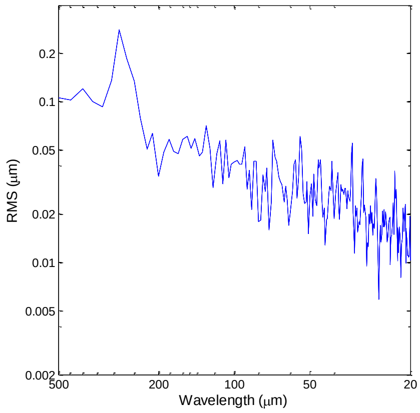
<td>
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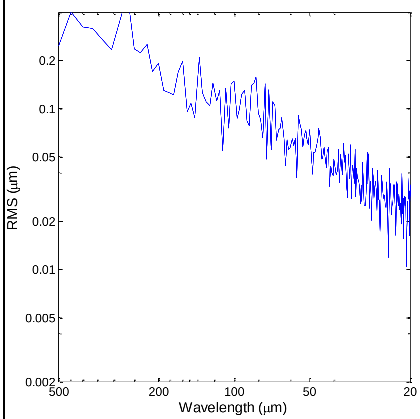
<td>
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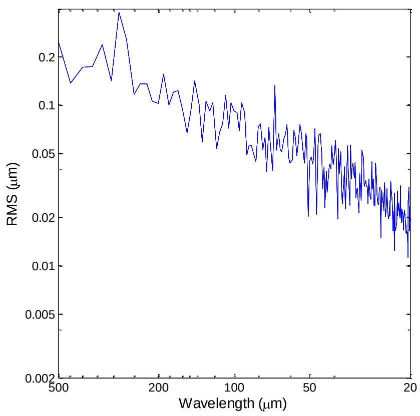
<td>
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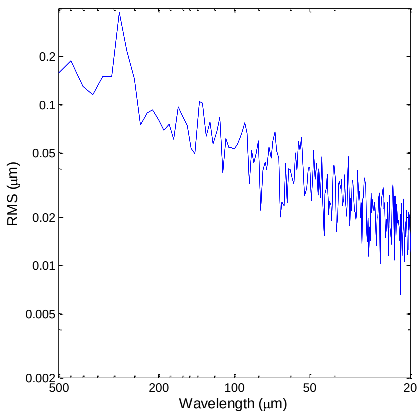
<td>
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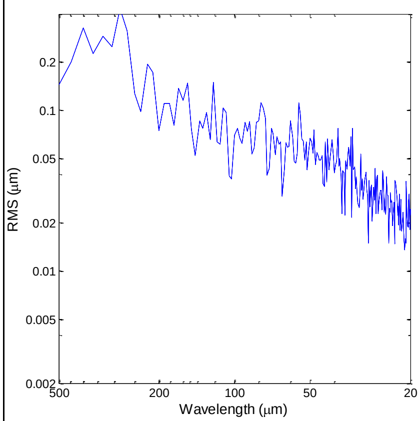
<td>
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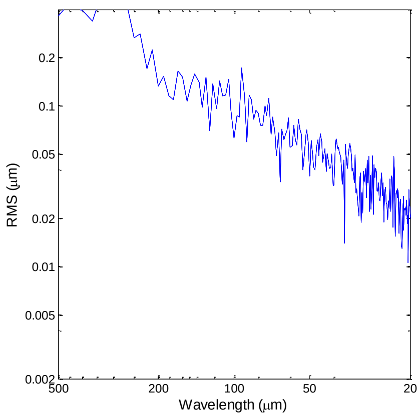
<td>
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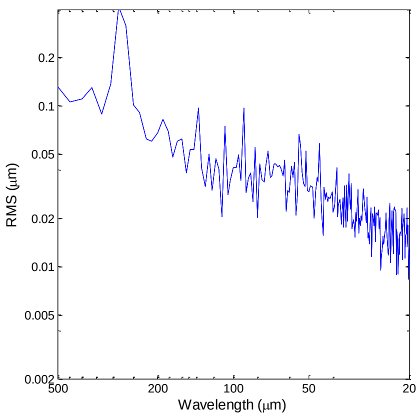
<td>
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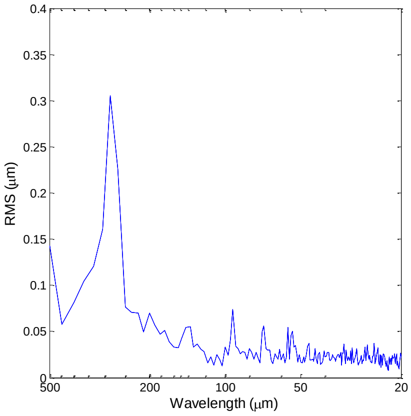
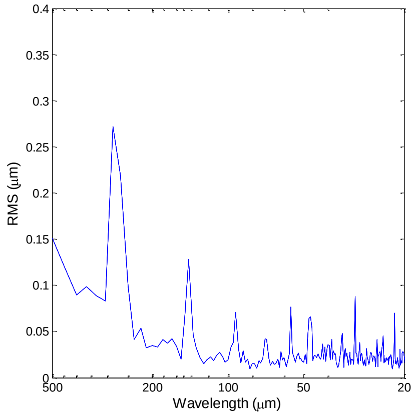
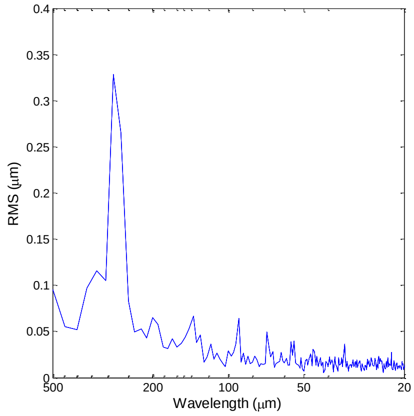
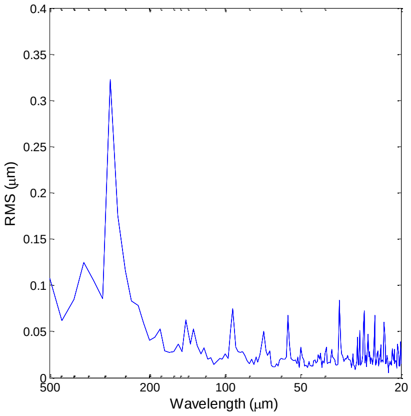
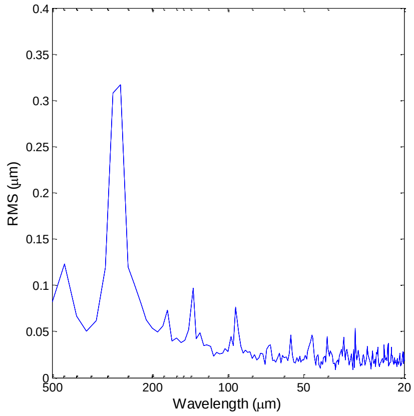
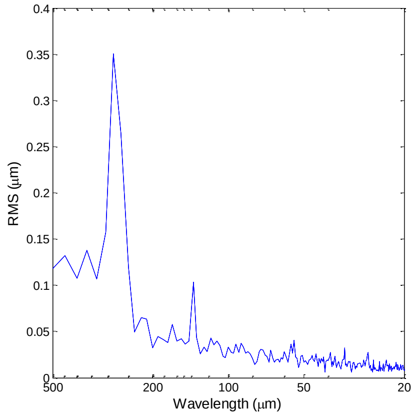
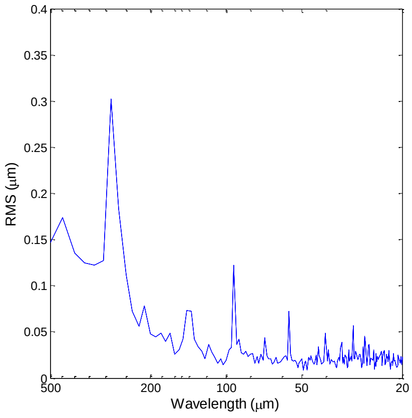
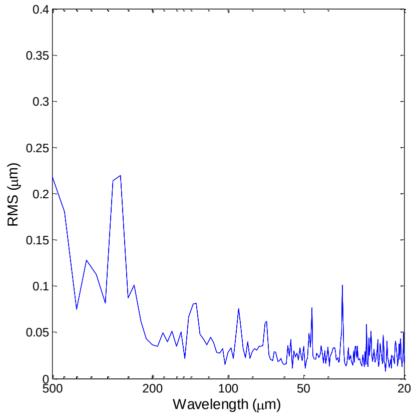
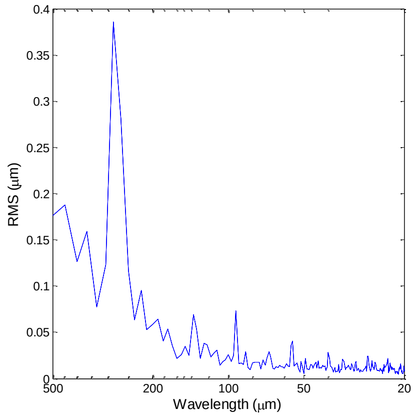
Appendix G2: Frequency analysis

Operator C: 19/04-2010

19.4. Operator C – low speed, feed 0.3mm/rev –linear scale			
	P_1%	P_10%	P_oil
Wp1			
Wp2			
Wp3			

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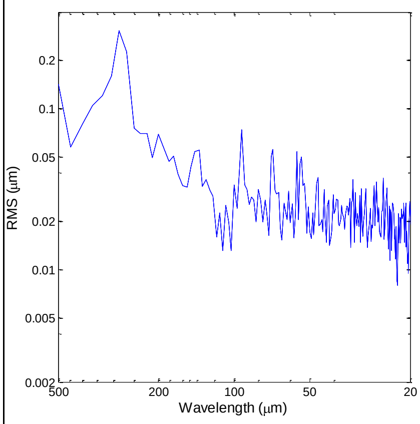
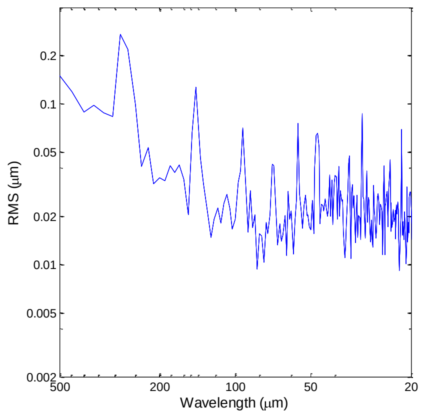
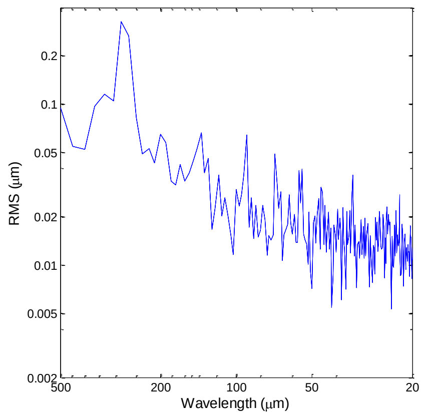
<td></td>
<td></td>
<td></td></tr>
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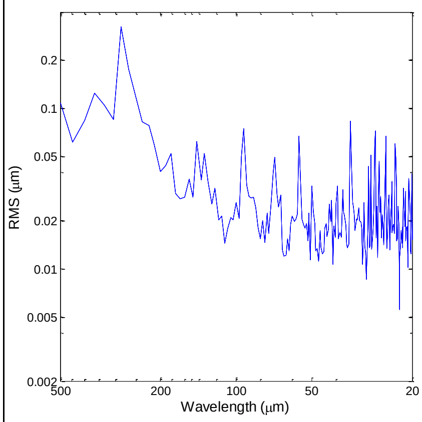
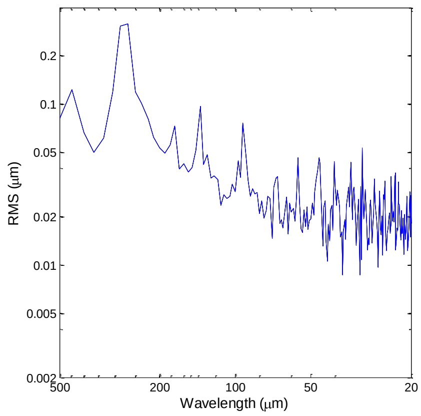
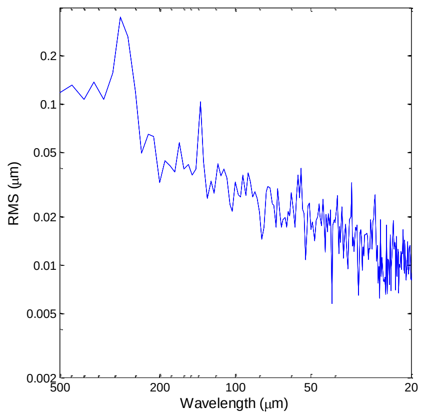
<td></td>
<td></td>
<td></td></tr>
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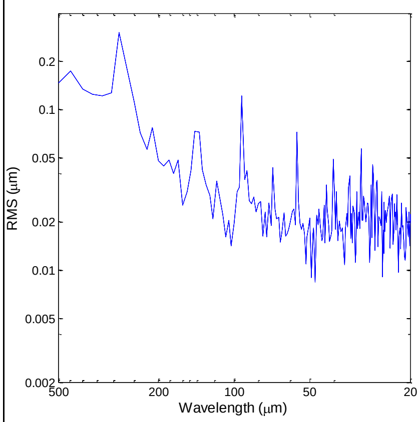
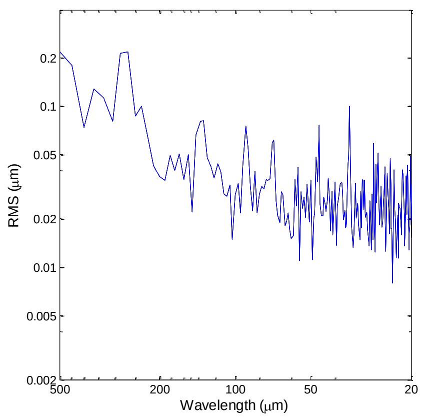
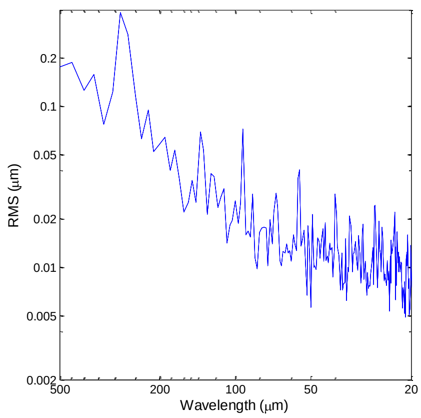
<td></td>
<td></td>
<td></td></tr>
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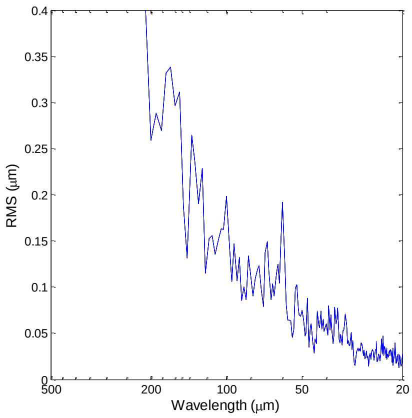
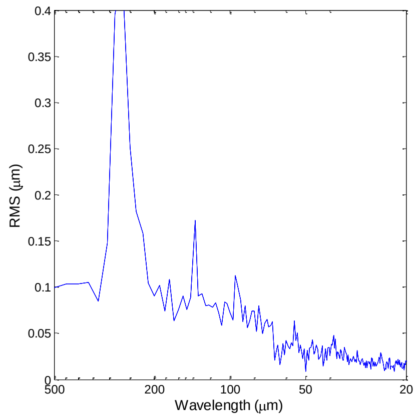
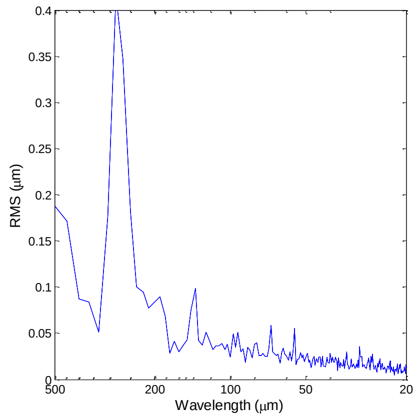
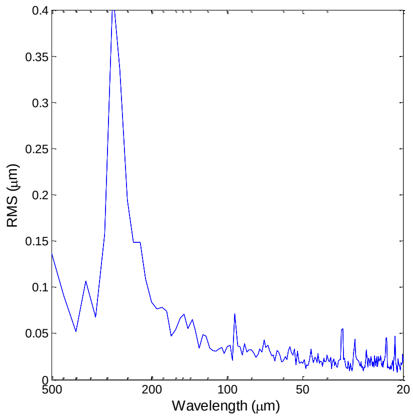
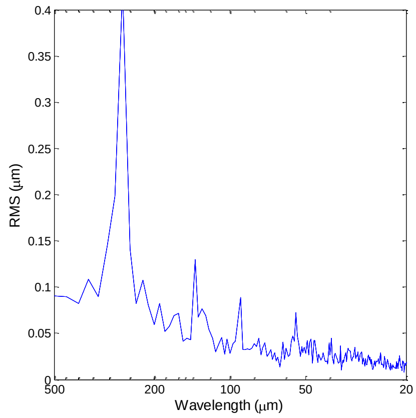
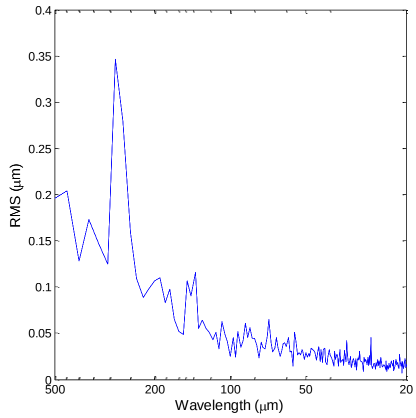
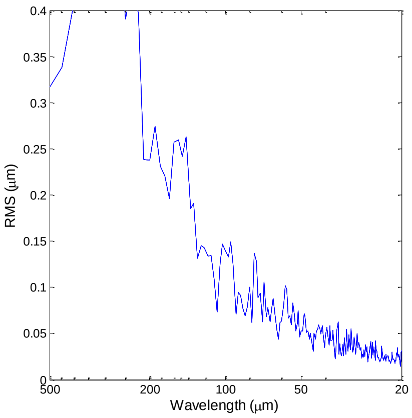
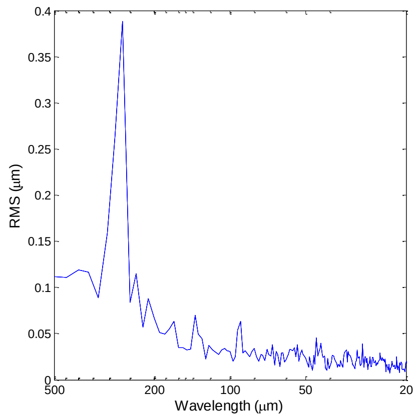
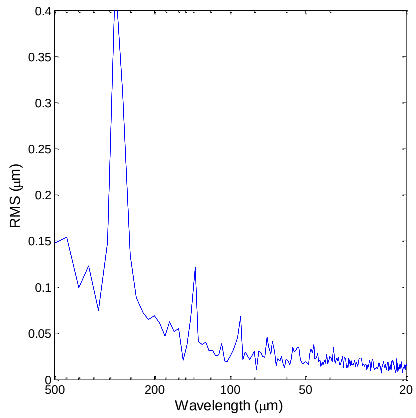
19.4. Operator C – high speed, feed 0.3mm/rev – linear scale			
	R_1%	R_10%	R_oil
Wp1			
Wp2			
Wp3			

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<tr><th colspan="4">19.4. Operator C – high speed, feed 0.3mm/rev – log scale</th></tr>
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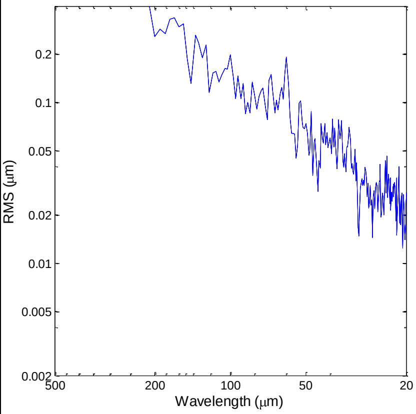
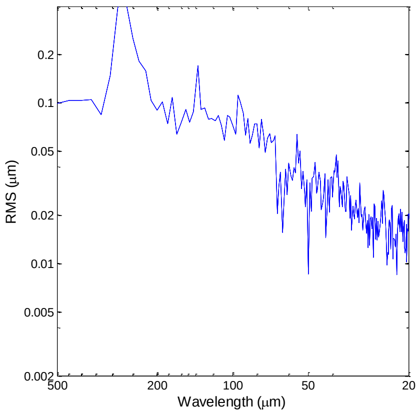
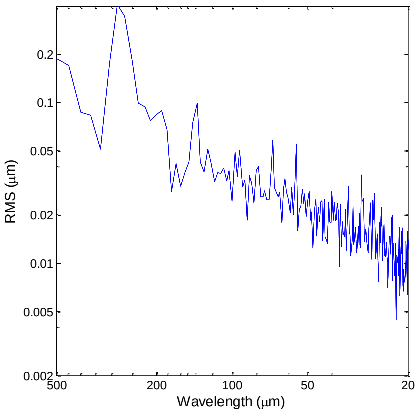
<td></td>
<td></td>
<td></td></tr>
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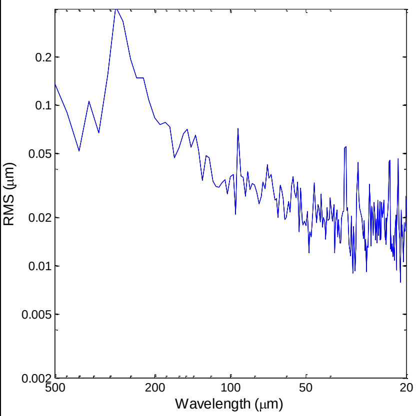
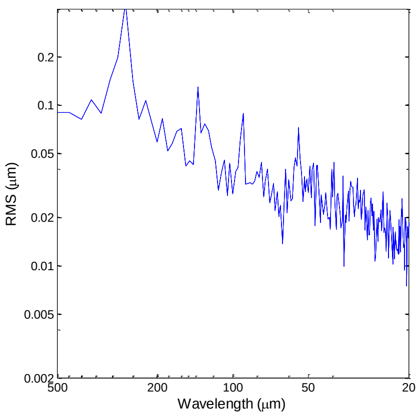
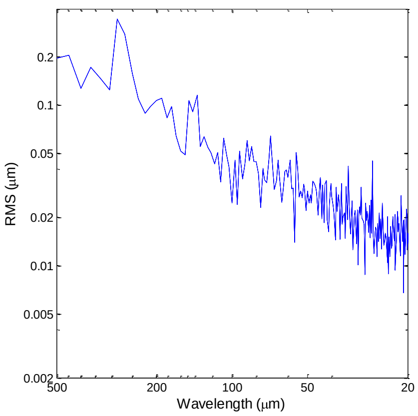
<td></td>
<td></td>
<td></td></tr>
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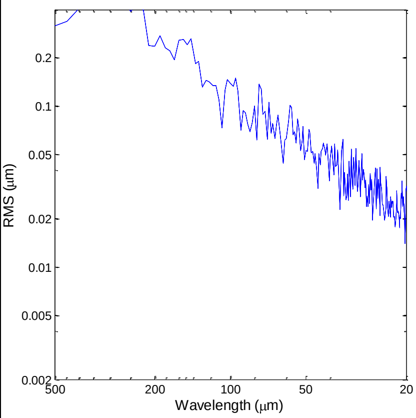
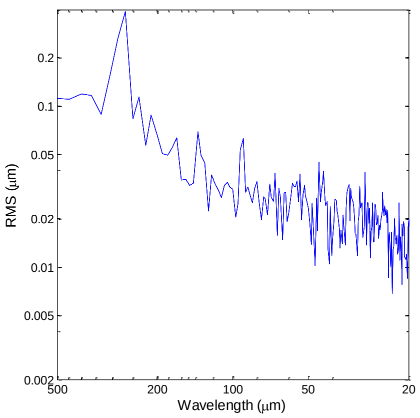
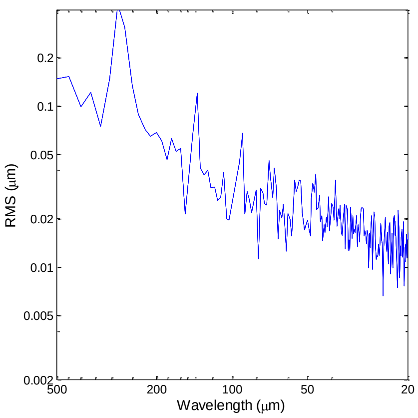
<td></td>
<td></td>
<td></td></tr>
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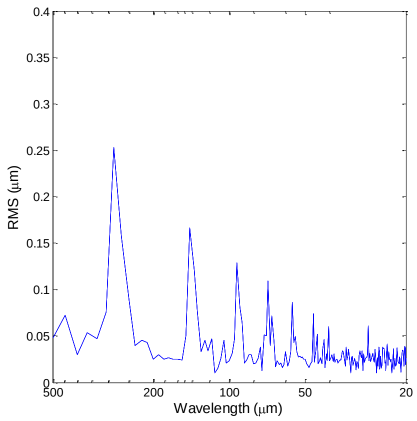
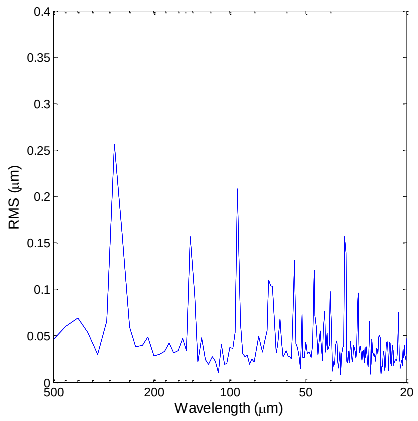
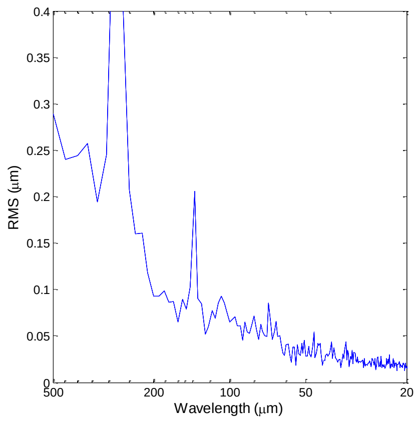
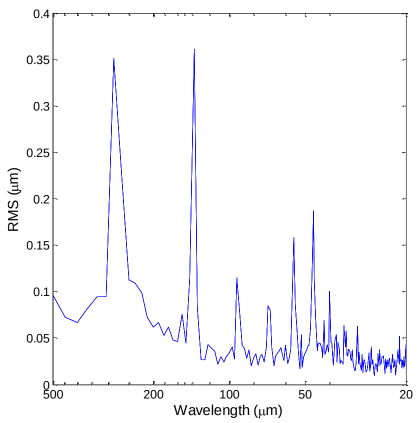
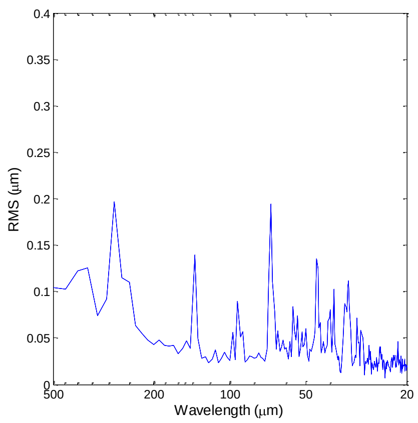
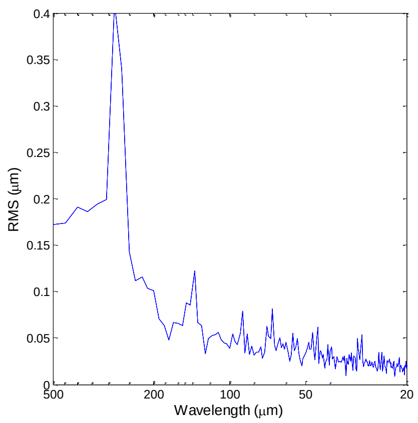
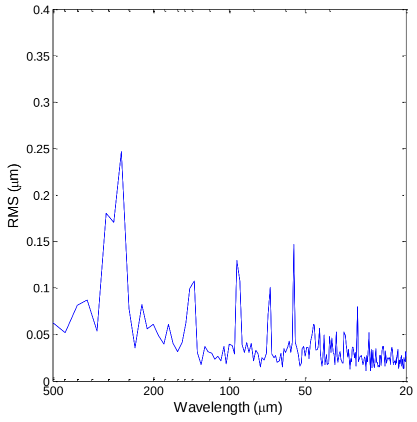
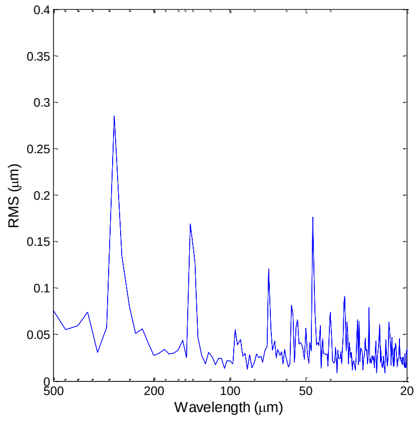
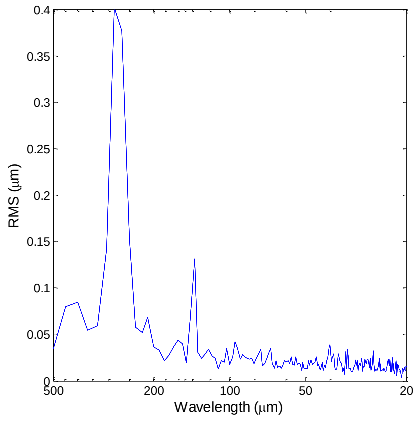
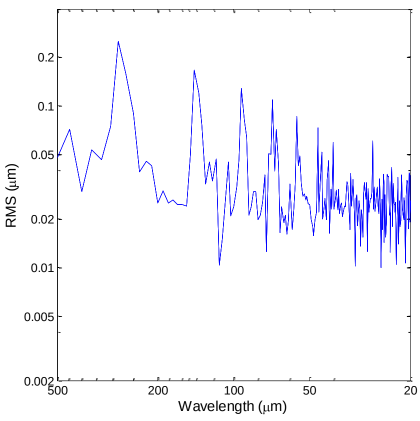
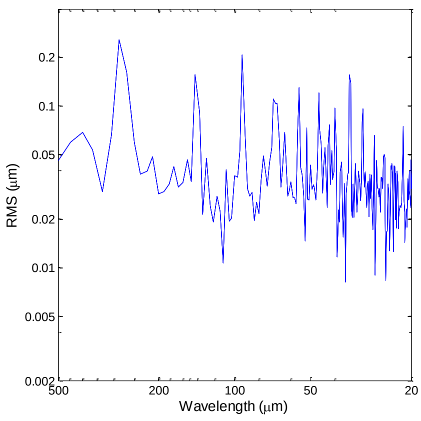
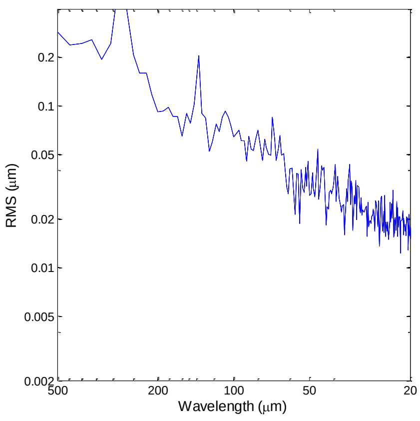
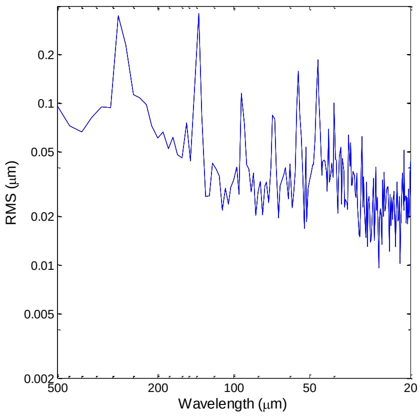
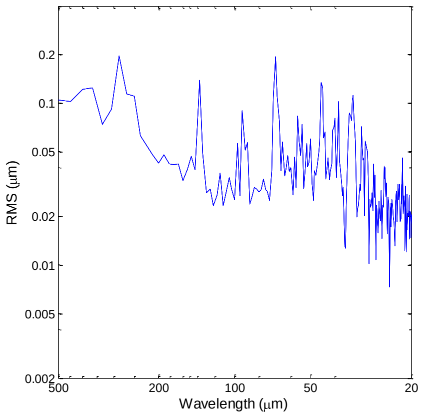
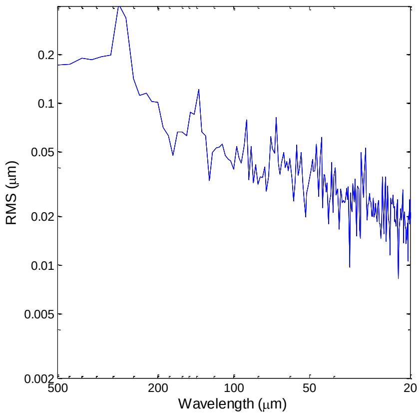
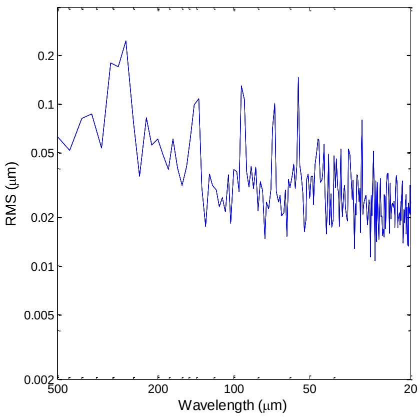
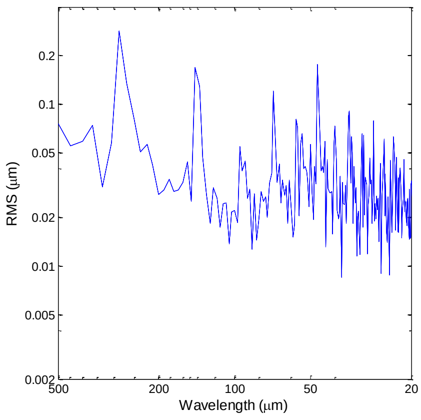
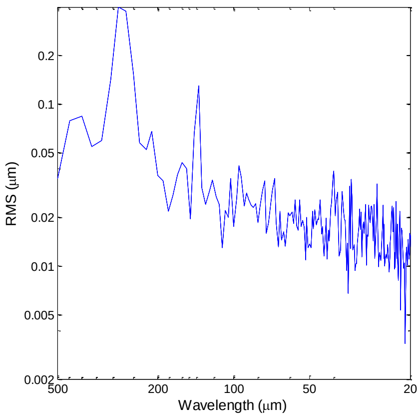
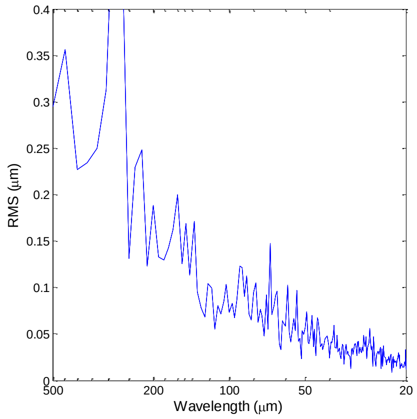
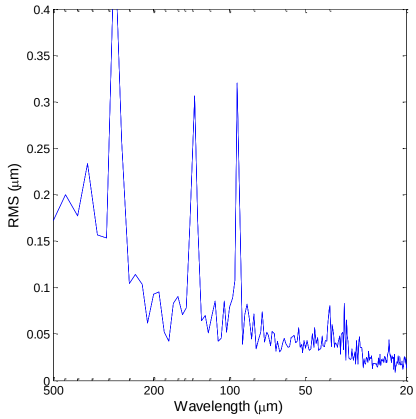
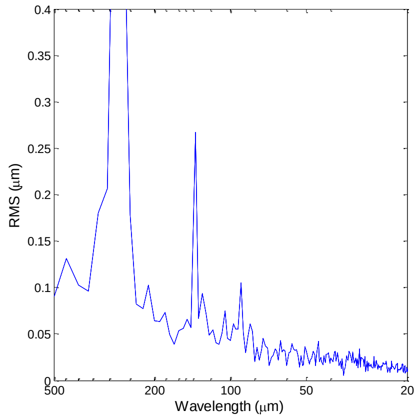
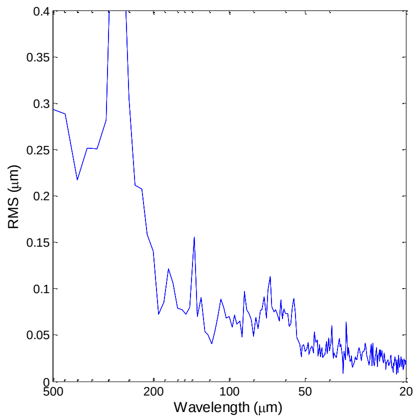
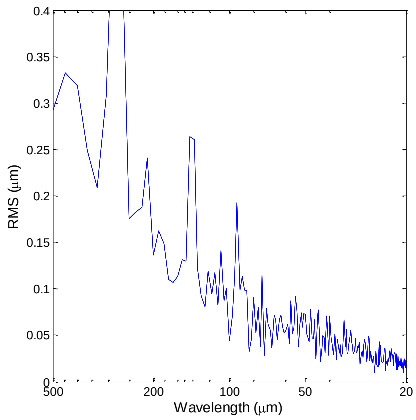
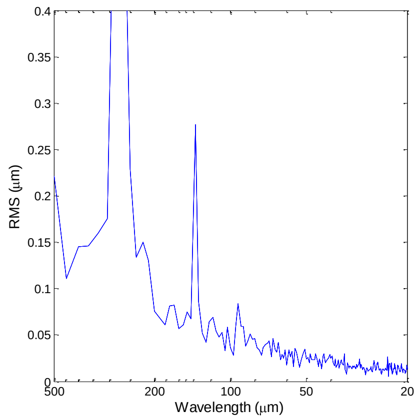
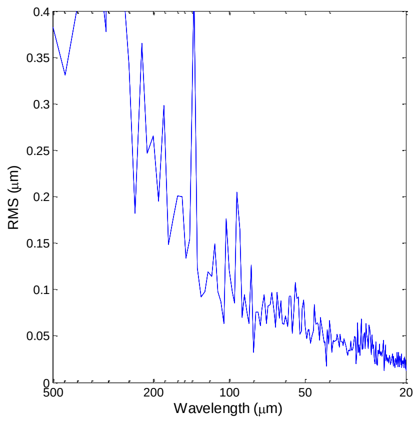
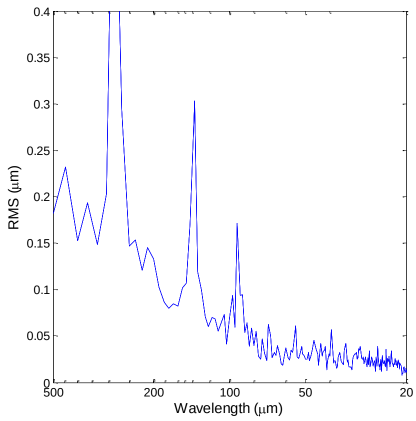
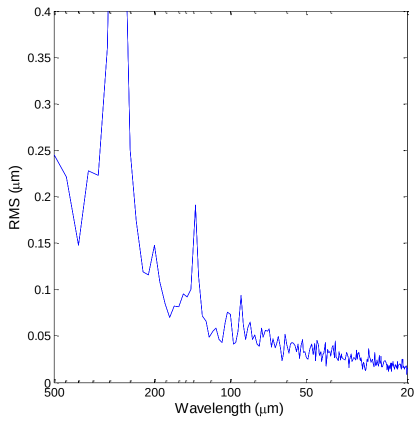
Appendix G3: Frequency analysis

Operator A: 26/04-2010

26.4. Operator A – low speed, feed 0.3mm/rev – linear scale			
	P_1%	P_10%	P_oil
Wp1			
Wp2			
Wp3			

26.4. Operator A – low speed, feed 0.3mm/rev – log scale			
	P_1%	P_10%	P_oil
Wp1			
Wp2			
Wp3			

26.4. Operator A – high speed, feed 0.3mm/rev –linear scale			
	R_1%	R_10%	R_oil
Wp1			
Wp2			
Wp3			

<table>
<tr><th colspan="4">26.4. Operator A – high speed, feed 0.3mm/rev – log scale</th></tr>
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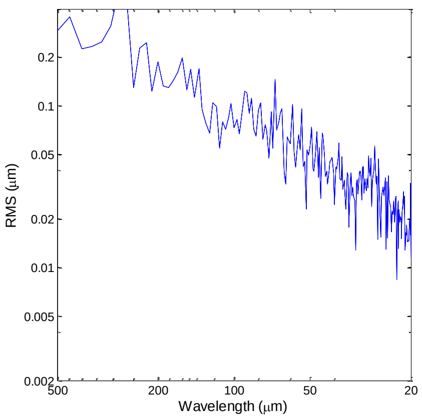
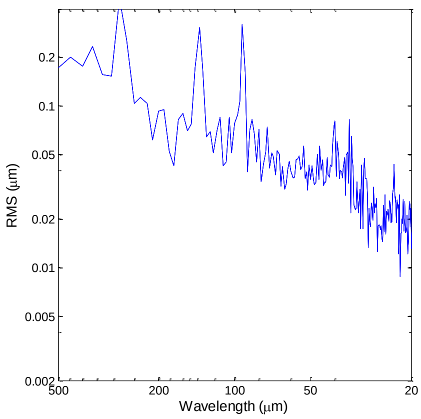
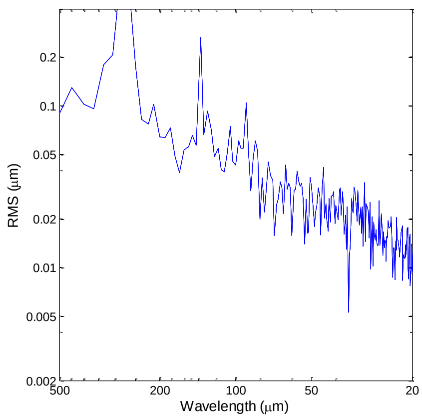
<tr><td>Wp1</td><td>
</td><td>
</td><td>
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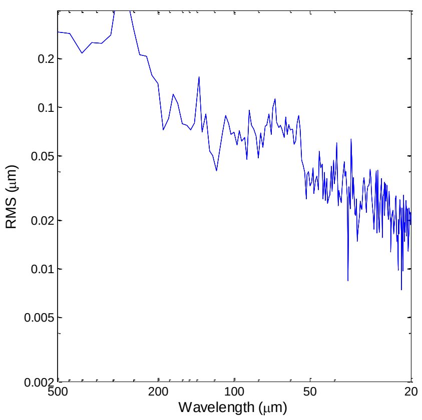
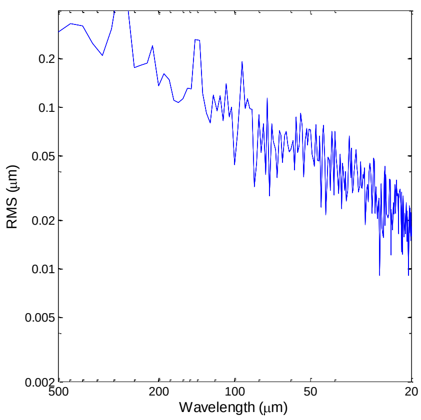
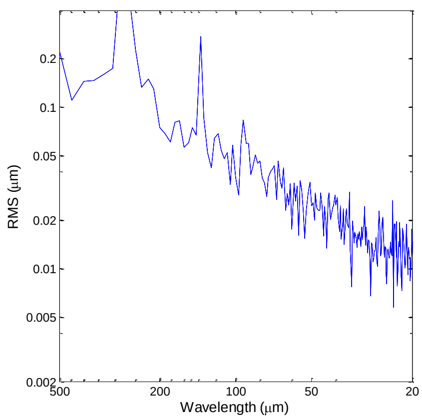
<tr><td>Wp2</td><td>
</td><td>
</td><td>
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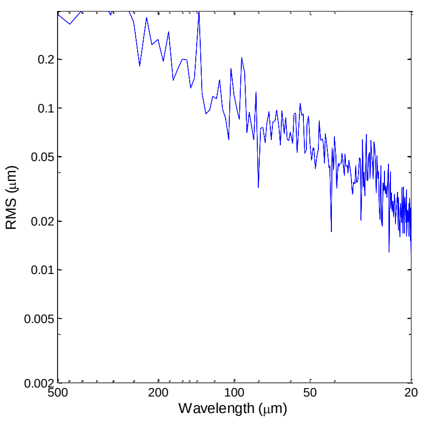
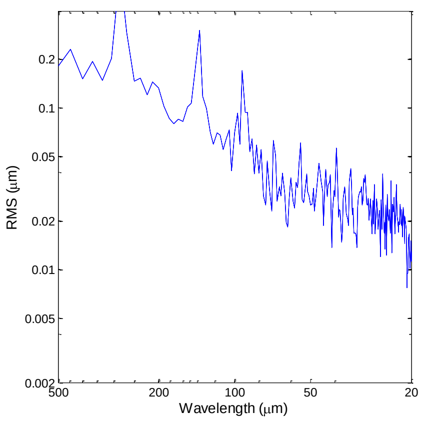
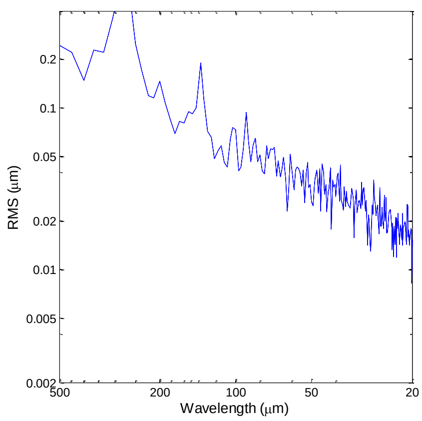
<tr><td>Wp3</td><td>
</td><td>
</td><td>
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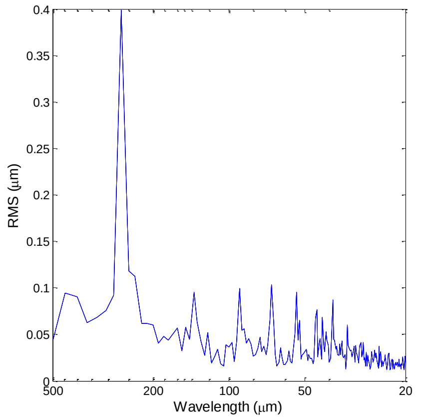
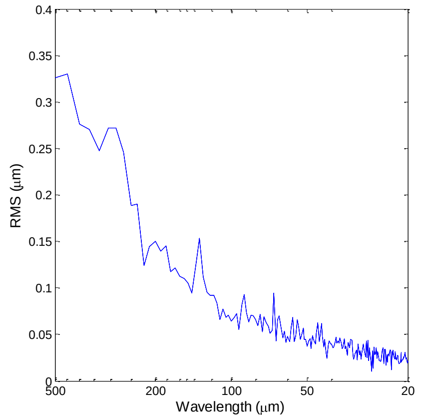
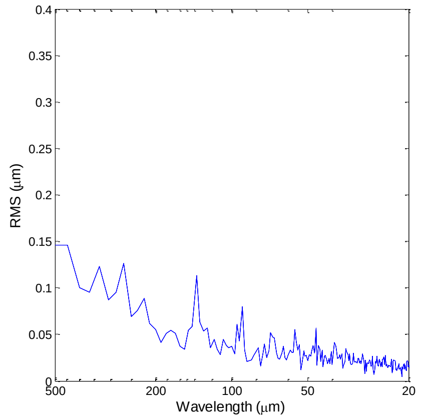
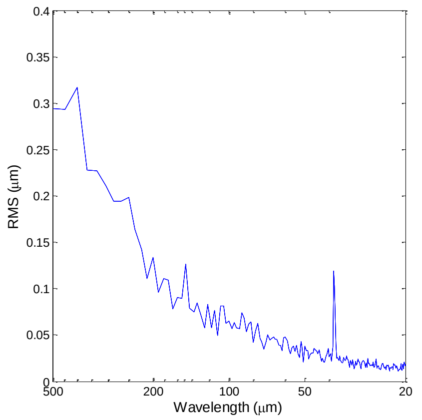
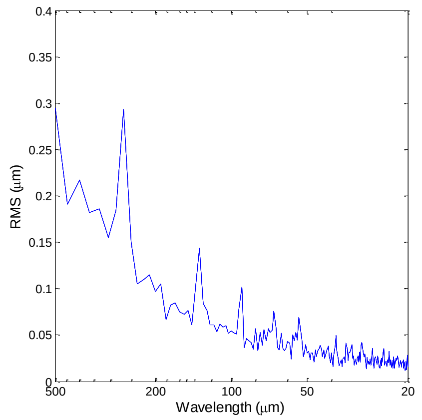
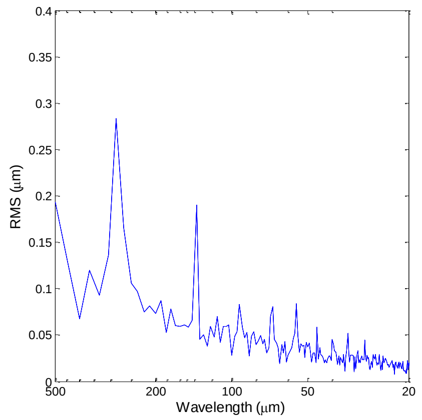
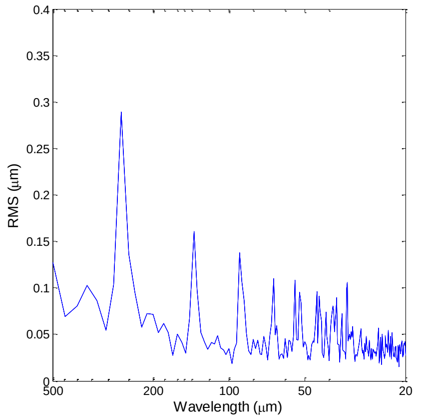
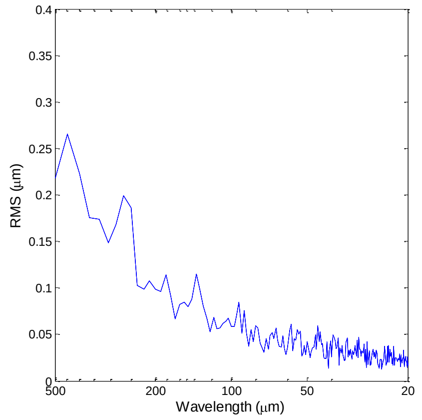
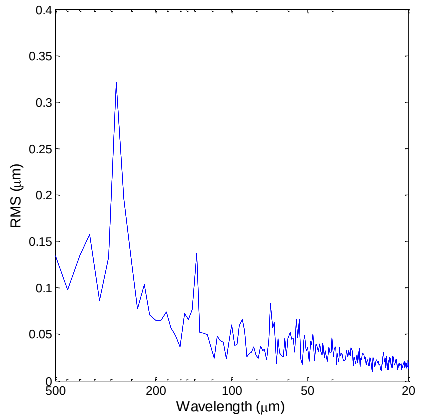
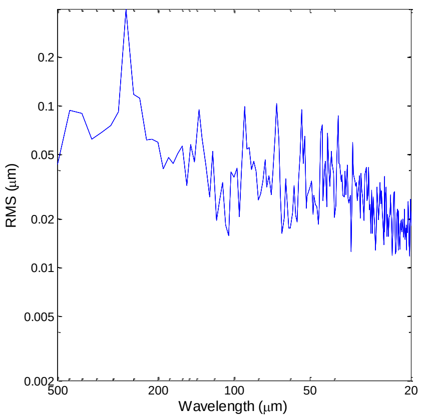
Appendix G4: Frequency analysis

Operator B: 12/04-2010

12.4. Operator B – low speed, feed 0.3mm/rev – linear scale			
	P_1%	P_10%	P_oil
Wp1			
Wp2			
Wp3			

<table>
<tr><th colspan="4">12.4. Operator B – low speed, feed 0.3mm/rev – log scale</th></tr>
<tr><th></th><th>P_1%</th><th>P_10%</th><th>P_oil</th></tr>
<tr><td>Wp1</td>
<td>
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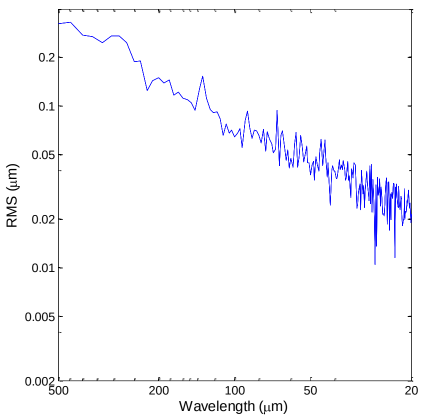
<td>
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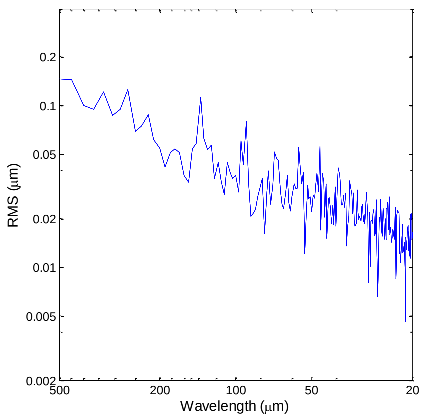
<td>
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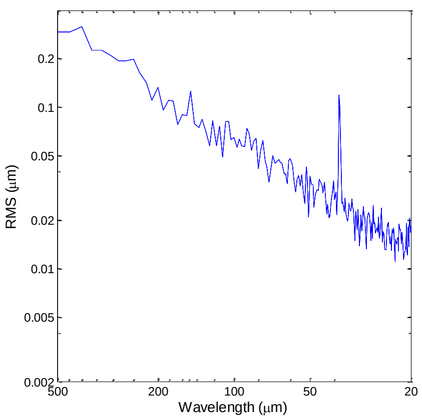
<tr><td>Wp2</td>
<td>
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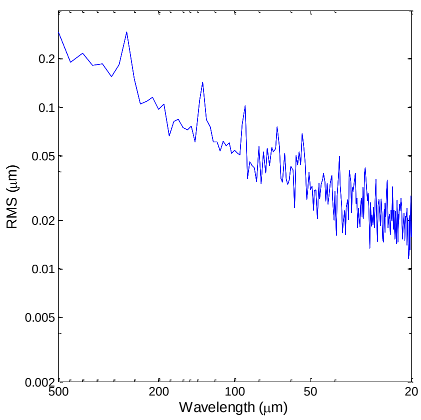
<td>
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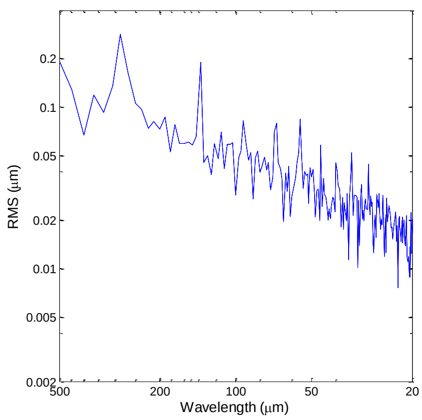
<td>
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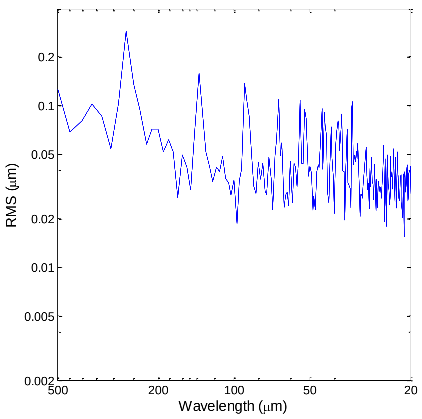
<td>
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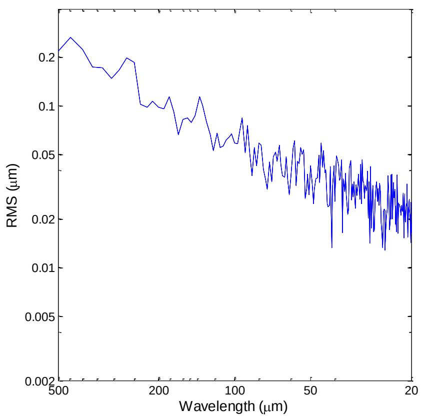
<td>
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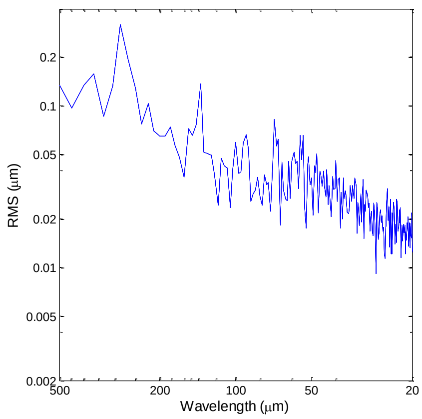
<td>
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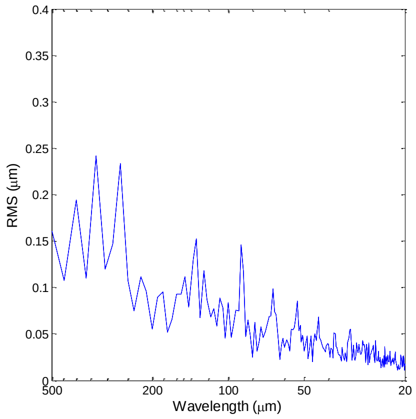
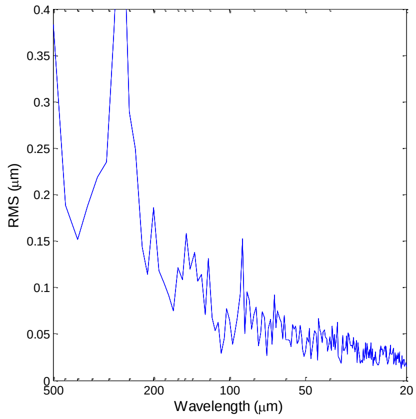
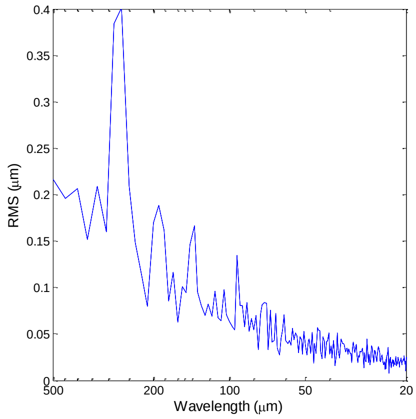
12.4. Operator B – high speed, feed 0.3mm/rev – linear scale

<table>
<tr><th></th><th>R_1%</th><th>R_10%</th><th>R_oil</th></tr>
<tr><td>Wp1</td><td>
</td><td>
</td><td>
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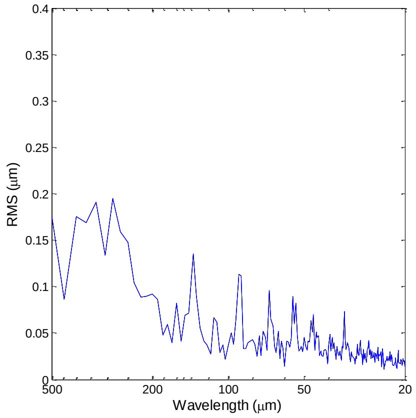
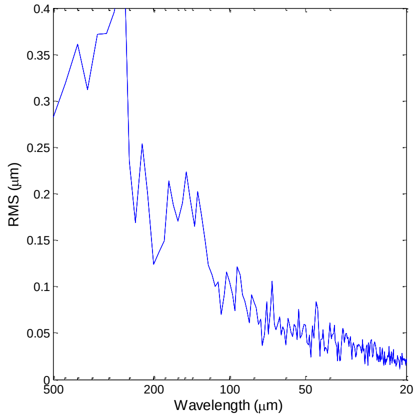
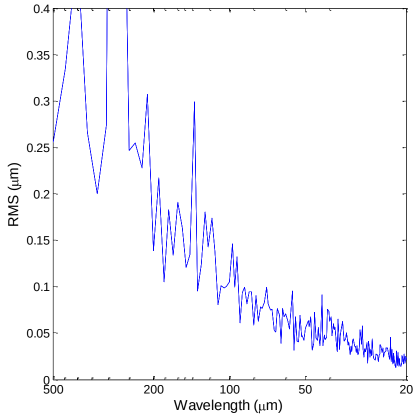
<tr><td>Wp2</td><td>
</td><td>
</td><td>
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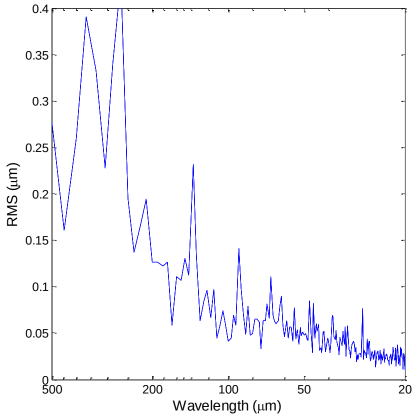
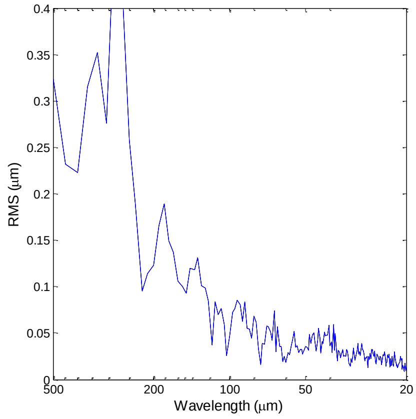
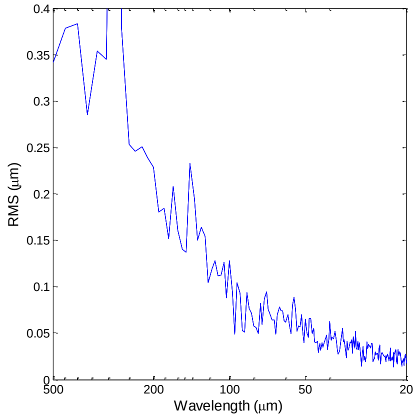
<tr><td>Wp3</td><td>
</td><td>
</td><td>
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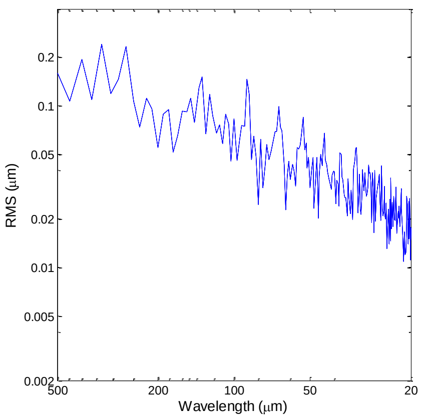
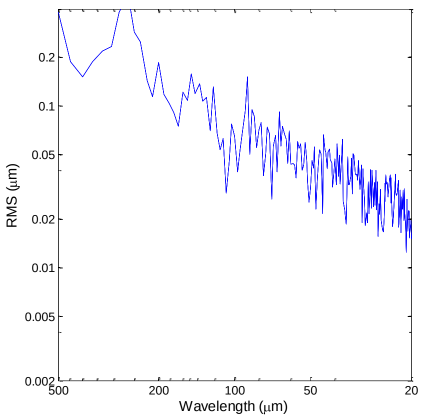
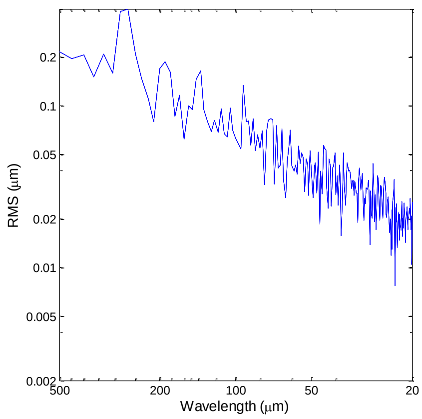
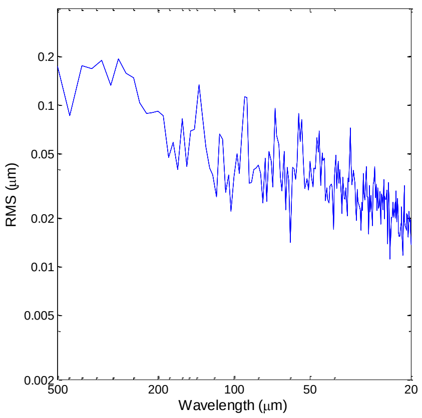
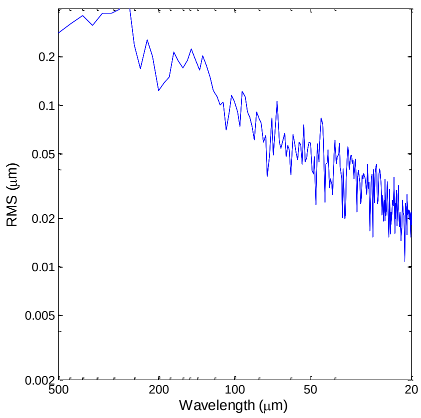
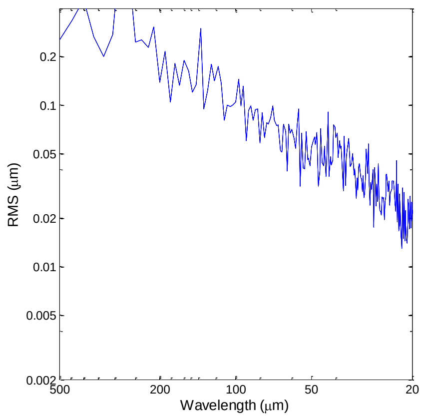
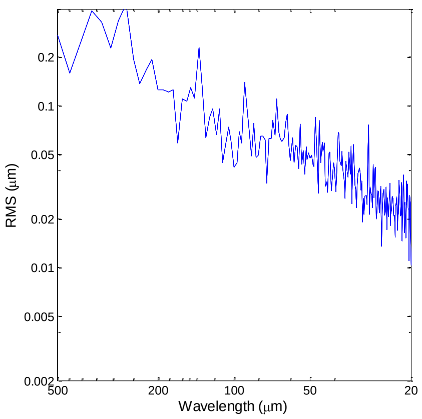
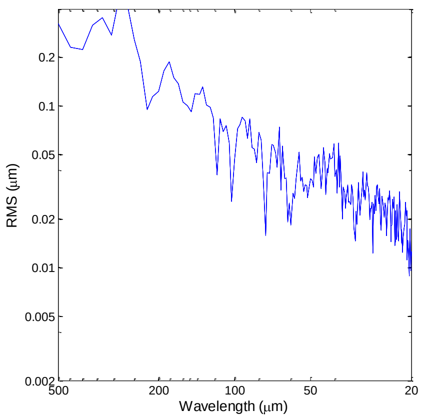
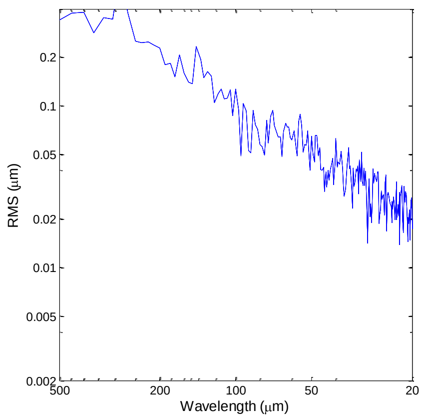
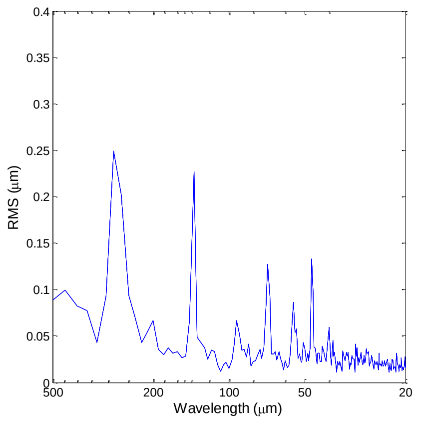
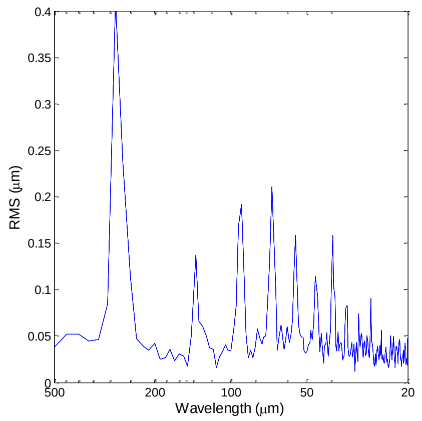
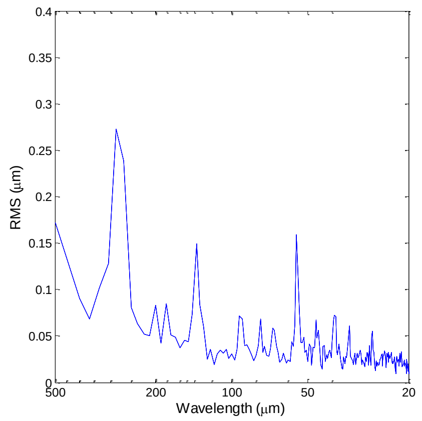
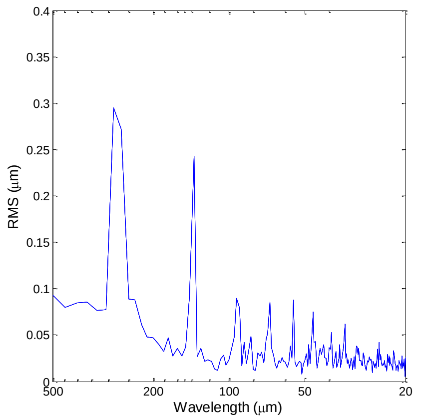
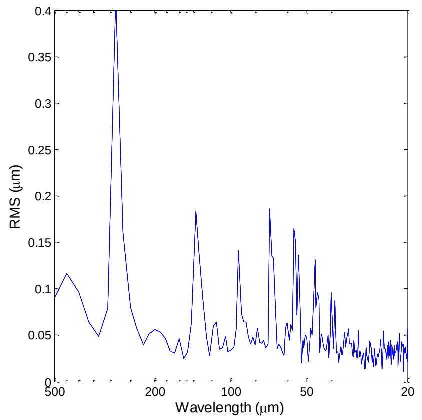
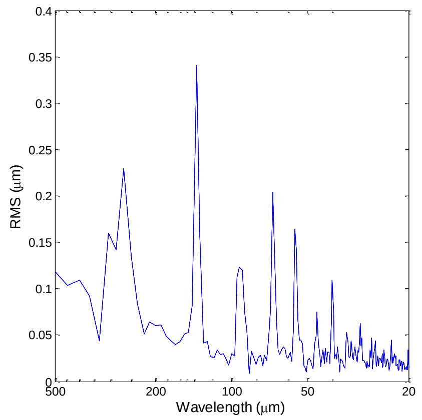
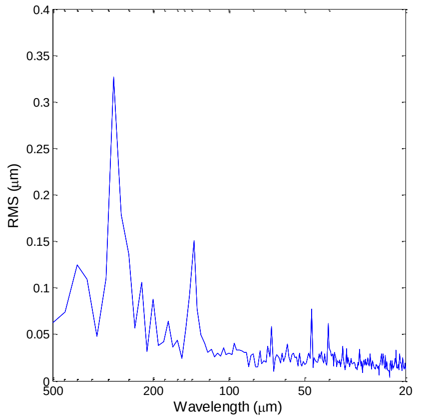
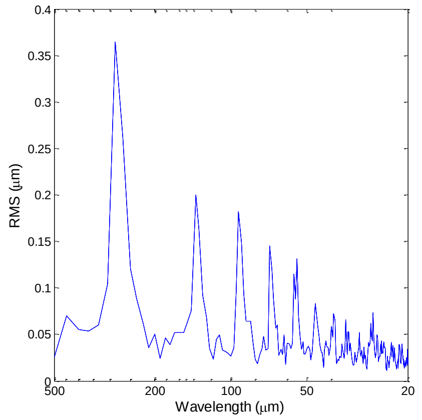
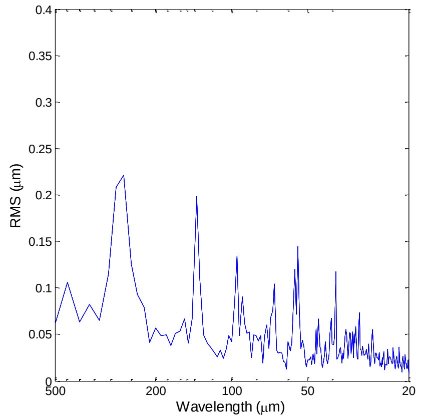
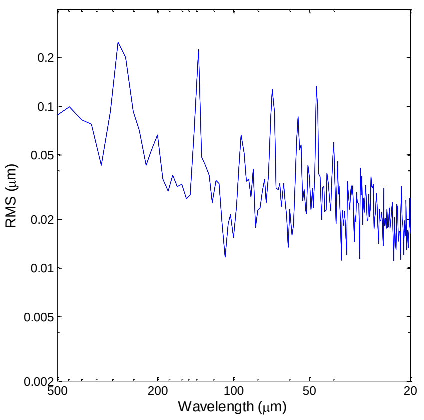
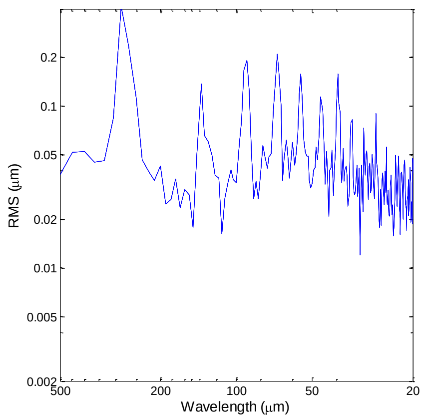
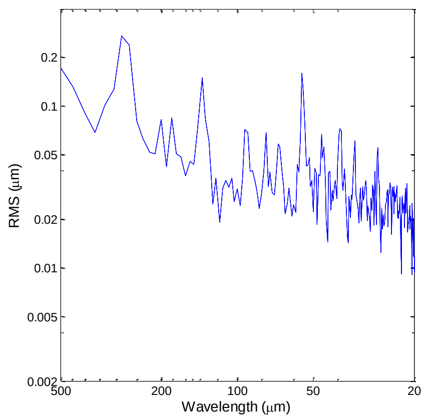
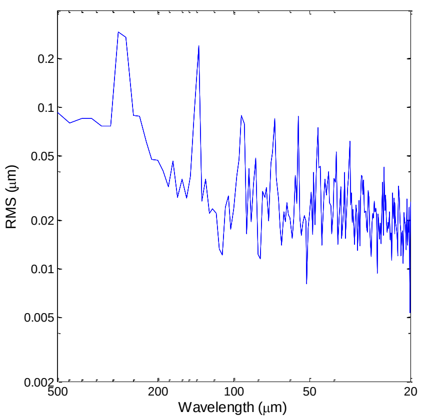
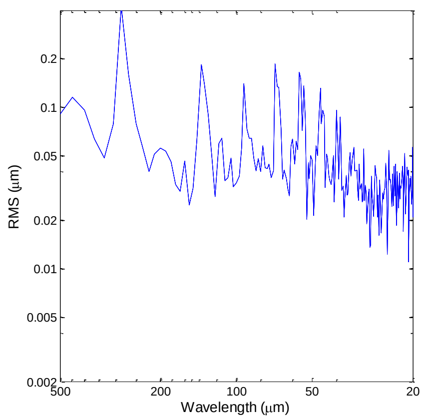
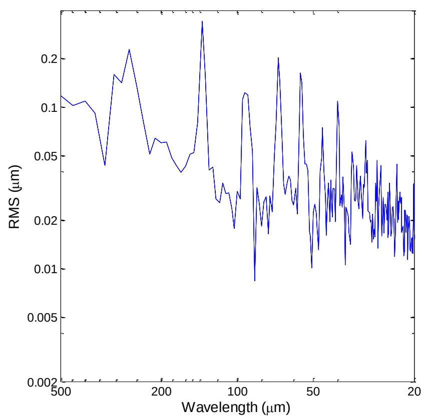
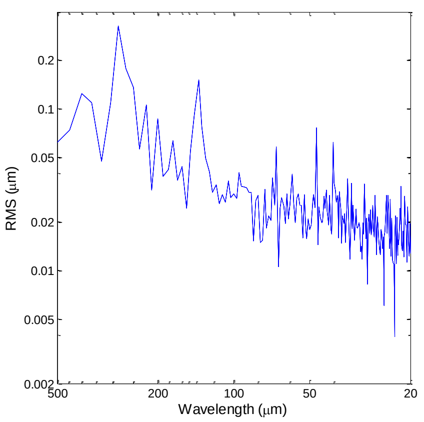
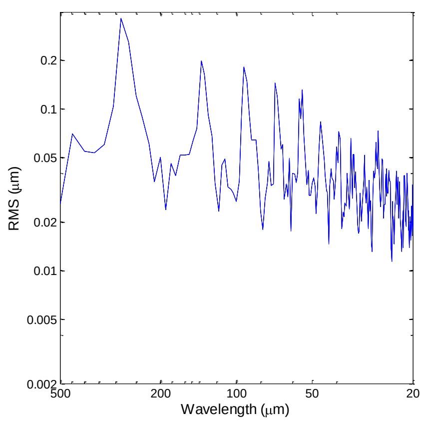
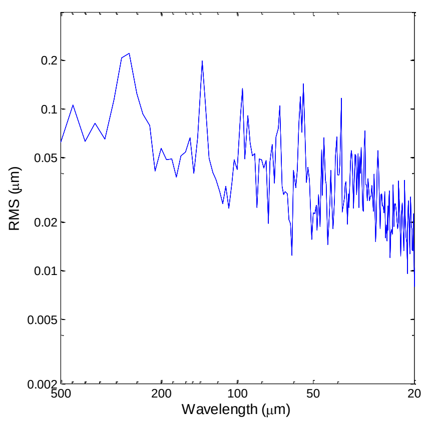
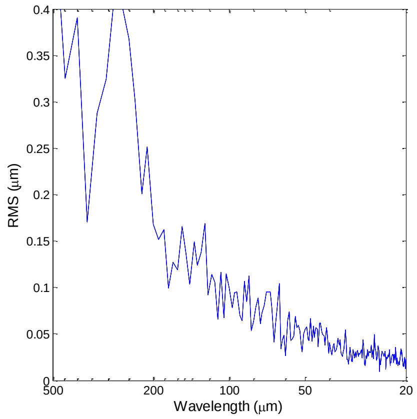
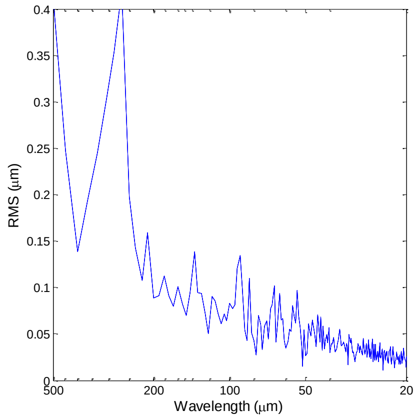
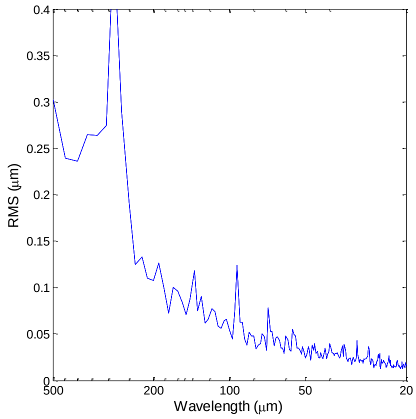
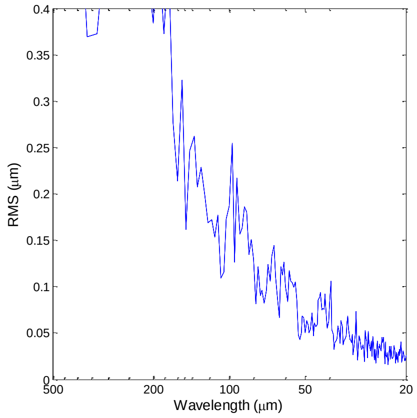
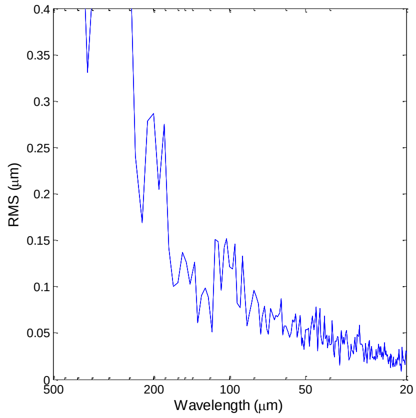
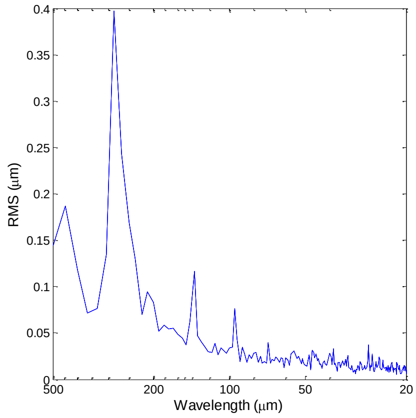
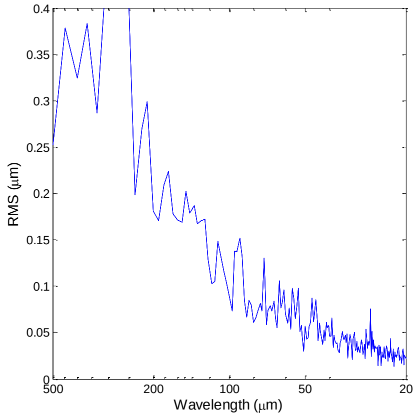
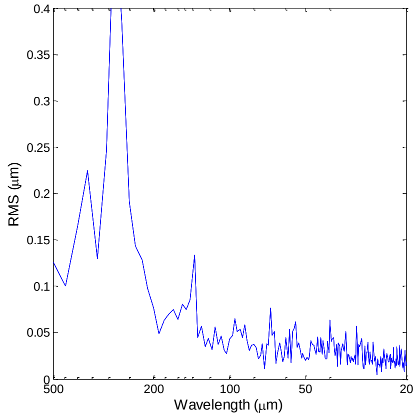
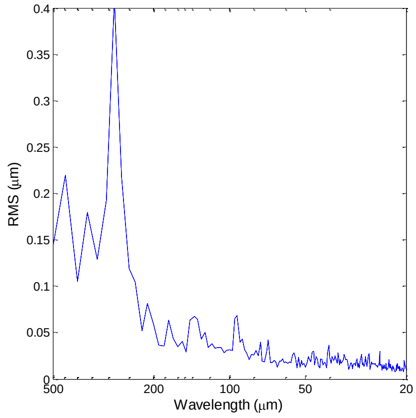
12.4. Operator B – high speed, feed 0.3mm/rev – log scale			
	R_1%	R_10%	R_oil
Wp1			
Wp2			
Wp3			

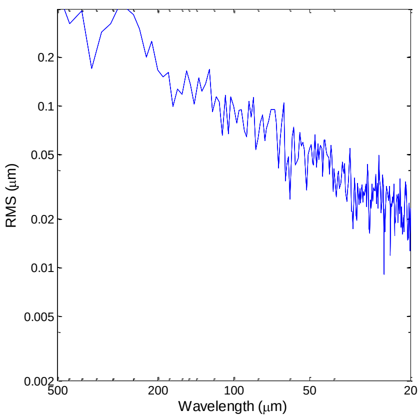
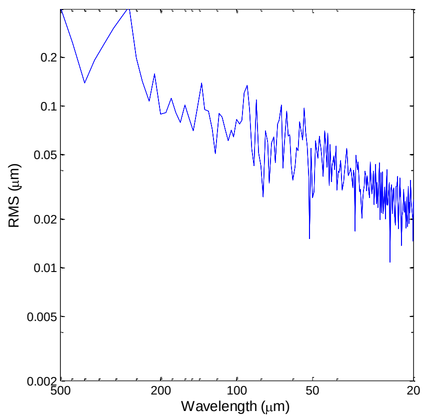
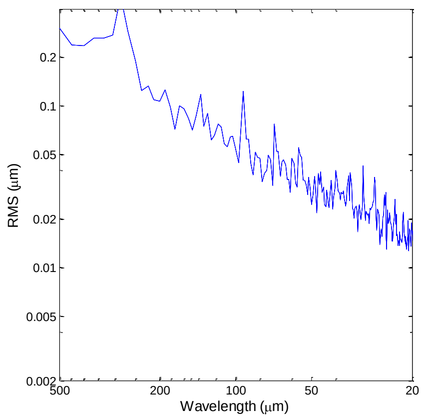
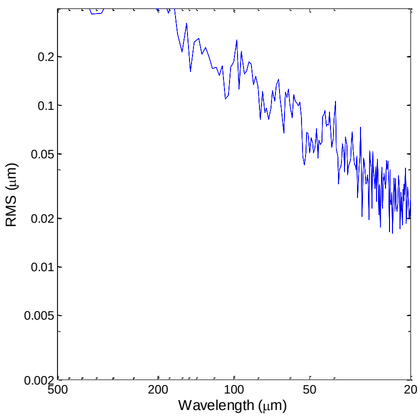
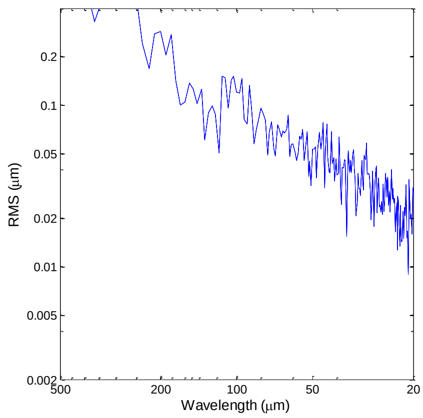
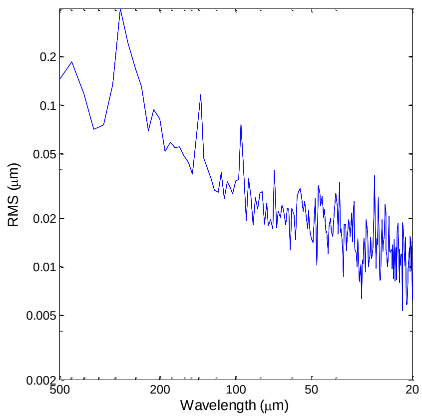
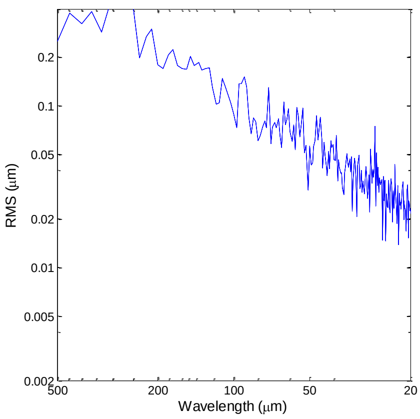
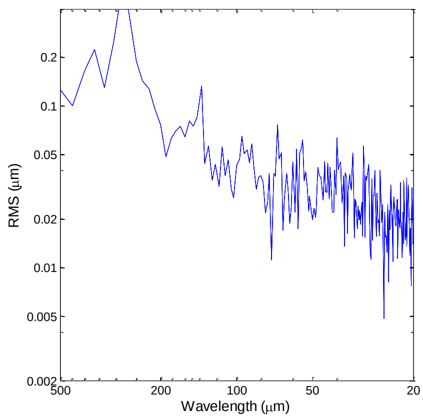
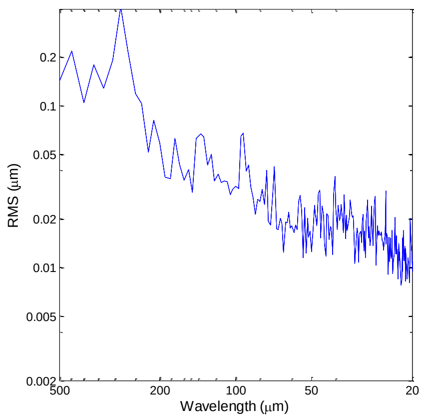
Appendix G5: Frequency analysis

Operator D: 03/05-2010

3.5. Operator D – low speed, feed 0.3mm/rev – linear scale			
	P_1%	P_10%	P_oil
Wp1			
Wp2			
Wp3			

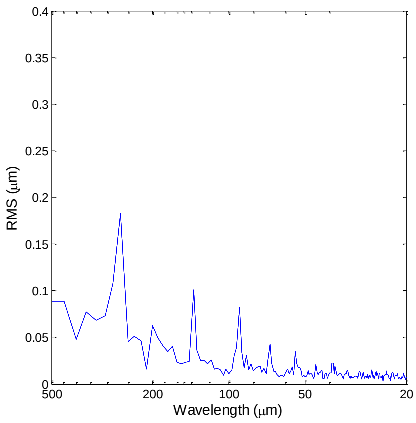
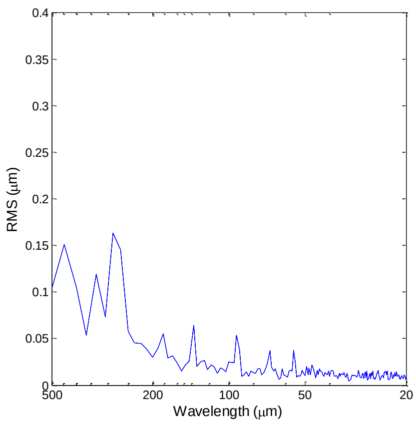
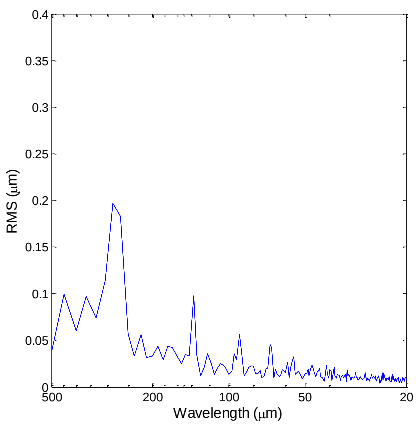
3.5. Operator D – low speed, feed 0.3mm/rev – log scale			
	P_1%	P_10%	P_oil
Wp1			
Wp2			
Wp3			

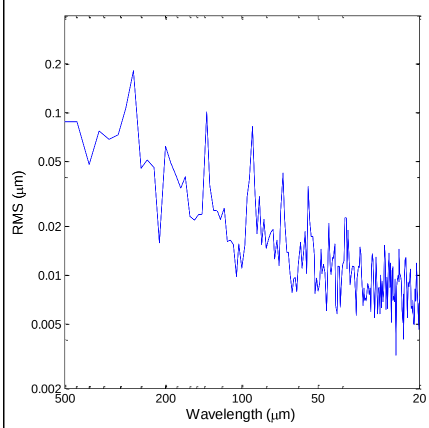
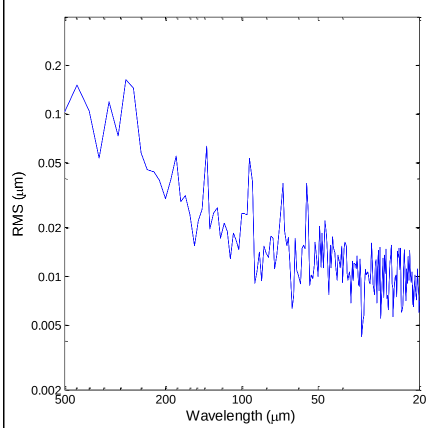
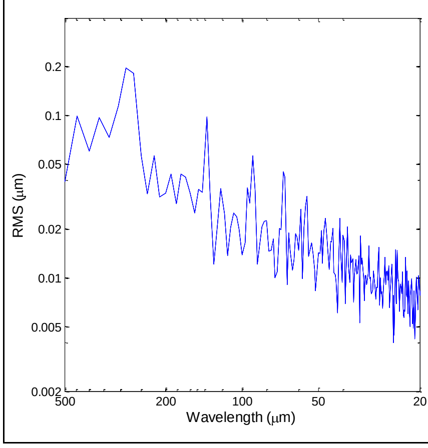
<table>
<tr><th colspan="4">3.5. Operator D – high speed, feed 0.3mm/rev – linear scale</th></tr>
<tr><th></th><th>R_1%</th><th>R_10%</th><th>R_oil</th></tr>
<tr><td>Wp1</td><td></td><td></td><td></td></tr>
<tr><td>Wp2</td><td></td><td></td><td></td></tr>
<tr><td>Wp3</td><td></td><td></td><td></td></tr>
</table>

<table>
<tr><th colspan="4">3.5. Operator D – high speed, feed 0.3mm/rev – log scale</th></tr>
<tr><th></th><th>R_1%</th><th>R_10%</th><th>R_oil</th></tr>
<tr><td>Wp1</td>
<td></td>
<td></td>
<td></td></tr>
<tr><td>Wp2</td>
<td></td>
<td></td>
<td></td></tr>
<tr><td>Wp3</td>
<td></td>
<td></td>
<td></td></tr>
</table>

Appendix G6: Frequency analysis

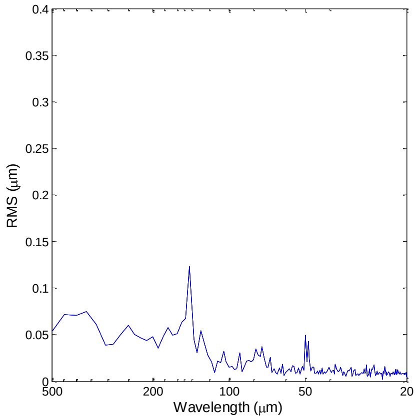
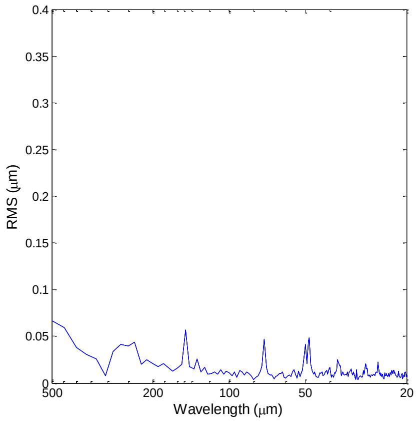
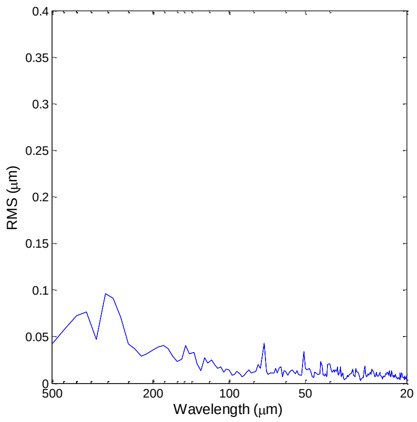
Operator F: 23/06-2010

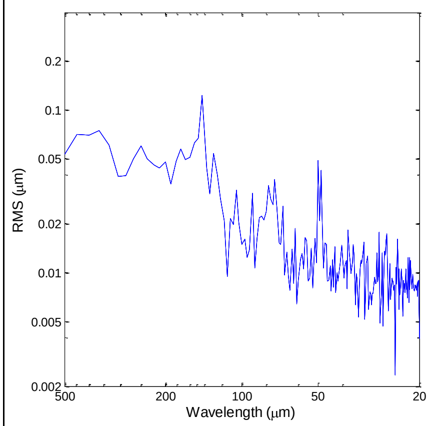
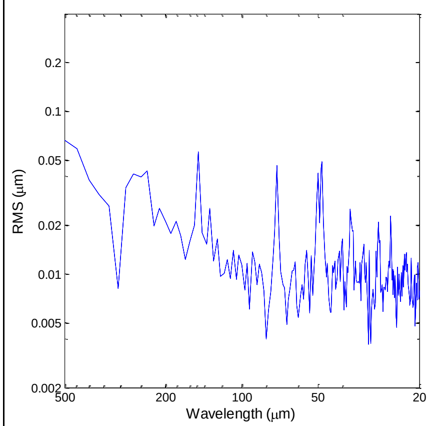
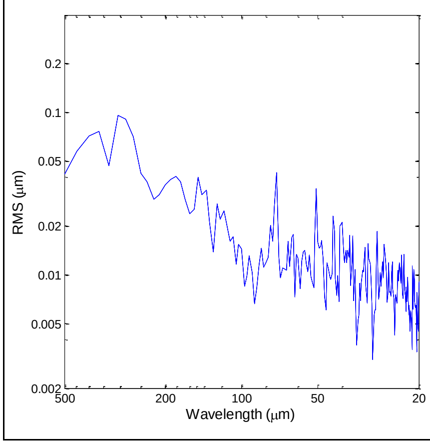
	23.6. Operator F – low speed, feed 0.3mm/rev – linear scale
	Neat oil – TDN81
Wp1	
Wp2	
Wp3	

23.6. - Operator F – low speed, feed 0.3mm/rev – log scale
Neat oil – TDN81




Appendix G7: Frequency analysis

Operator G: 23/06-2010

	23.6. Operator G – low speed, feed 0.2mm/rev –linear scale
	Neat oil – TDN81
Wp1	
Wp2	
Wp3	

23.6. Operator G – low speed, feed 0.2mm/rev – log scale
Neat oil – TDN81




Appendix H

Microhardness measurement

Appendix H contains tables from all microhardness measurements.

Measuring strategy is explained in Section 2.3.4.

Table H1: Microhardness measurement results – P0.3/W1.

	Operator E, 23.3.2010, f=0.3mm/rev, reamer Ø10.2mm						
	P3 / 1% (P0.3/W1)						
	Distance from the edge [mm]						
Repetition	0.05	0.10	0.15	0.30	0.60	1.20	2.40
1	247	217	182	167	169	166	169
2			172	160	166	172	172
3	253	225	180	170	172	172	176
4			197	172	168	169	175
5	290	233	203	168	178	175	175
avg	263.3	225.0	186.8	167.4	170.6	170.8	173.4
std	23.3	8.0	12.8	4.6	4.7	3.4	2.9

Table H2: Microhardness measurement results – P0.3/W2.

	Operator E, 23.3.2010, f=0.3mm/rev, reamer Ø10.2mm						
	P1 / 10% (P0.3/W2)						
	Distance from the edge [mm]						
Repetition	0.05	0.10	0.15	0.30	0.60	1.20	2.40
1	270	251	199	186	168	168	169
2			175	161	165	169	168
3	270	225	182	162	170	172	169
4			196	169	169	169	170
5	260	222	193	169	169	166	165
avg	266.7	232.7	189.0	169.4	168.2	168.8	168.2
std	5.8	15.9	10.1	10.0	1.9	2.2	1.9

Table H3: Microhardness measurement results – P0.3/M.

	Operator E, 23.3.2010, f=0.3mm/rev, reamer Ø10.2mm						
	P1 / mineral oil (P0.3/M)						
	Distance from the edge [mm]						
Repetition	0.05	0.10	0.15	0.30	0.60	1.20	2.40
1	258	212	169	178	179	178	176
2			158	176	169	170	170
3	216	203	167	169	168	175	169
4			170	169	172	166	169
5	233	209	175	167	169	164	170
avg	235.7	208.0	167.8	171.8	171.4	170.6	170.8
std	21.1	4.6	6.2	4.9	4.5	5.9	2.9

Table H4: Microhardness measurement results – R0.3/W1.

	Operator E, 23.3.2010, f=0.3mm/rev, reamer Ø10.2mm						
	R2 / 1% (R0.3/W1)						
	Distance from the edge [mm]						
Repetition	0.05	0.10	0.15	0.30	0.60	1.20	2.40
1	276	264	201	171	170	169	162
2			192	169	169	162	163
3	297	242	200	170	164	166	166
4			204	162	164	166	166
5	279	235	184	164	166	167	166
avg	284.0	247.0	196.2	167.2	166.6	166.0	164.6
std	11.4	15.1	8.1	4.0	2.8	2.5	1.9

Table H5: Microhardness measurement results – R0.3/W2.

	Operator E, 23.3.2010, f=0.3mm/rev, reamer Ø10.2mm						
	R1 / 10% (R0.3/W2)						
	Distance from the edge [mm]						
Repetition	0.05	0.10	0.15	0.30	0.60	1.20	2.40
1	292	254	186	178	172	172	173
2			186	167	169	176	171
3	260	254	190	179	167	167	171
4			195	176	173	169	172
5	317	245	206	177	175	170	173
avg	289.7	251.0	192.6	175.4	171.2	170.8	172.0
std	28.6	5.2	8.4	4.8	3.2	3.4	1.0

Table H6: Microhardness measurement results – R0.3/M.

	Operator E, 23.3.2010, f=0.3mm/rev, reamer Ø10.2mm						
	R1 / mineral oil (R0.3/M)						
	Distance from the edge [mm]						
Repetition	0.05	0.10	0.15	0.30	0.60	1.20	2.40
1	235	221	178	172	169	172	168
2			170	162	162	169	163
3	227	227	168	166	162	165	172
4			172	167	160	170	167
5	245	221	171	161	164	167	170
avg	235.7	223.0	171.8	165.6	163.4	168.6	168.0
std	9.0	3.5	3.8	4.4	3.4	2.7	3.4

Table H7: Microhardness measurement results – P0.3/N.

	Operator F, 22.6.2010, f=0.3mm/rev, New reamer Ø10.2mm						
	P2 / neat oil (P0.3/N)						
	Distance from the edge [mm]						
Repetition	0.05	0.10	0.15	0.30	0.60	1.20	2.40
1	260	228	186	170	167	168	170
2			175	174	168	175	172
3	230	199	173	166	166	169	168
4			170	169	169	166	169
5	219	206	173	169	169	165	170
avg	236.3	211.0	175.4	169.6	167.8	168.6	169.8
std	21.2	15.1	6.2	2.9	1.3	3.9	1.5

Table H8: Microhardness measurement results – P0.2/N.

	Operator G, 22.6.2010, f=0.2mm/rev, New reamer Ø10.2mm						
	P2 / neat oil (P0.2/N)						
	Distance from the edge [mm]						
Repetition	0.05	0.10	0.15	0.30	0.60	1.20	2.40
1	266	237	194	181	169	172	169
2			182	173	166	166	168
3	256	212	174	166	164	166	169
4			166	169	162	166	166
5	215	205	169	162	166	167	166
avg	245.7	218.0	177.0	170.2	165.4	167.4	167.6
std	27.0	16.8	11.3	7.3	2.6	2.6	1.5

Appendix I

Calibration certificate

Appendix I contains a calibration certificate for below mentioned specifications:

Object: Roughness Standard ISO 5436 type C

Type: 528 RS-5

Serial number: P1167

Date of calibration: 19.6.2007

CGM
CENTER FOR GEOMETRISK METROLOGI

DANAK
CAL Reg.Nr. 273

Kalibreringscertifikat
Calibration Certificate

Antal Bilag **1**
No of Enclosures **1**
Rou07017

Certifikat nr. Certificate No.	**Rou07017**
Objekt Object	**Ruhedsnormal / Roughness Standard ISO 5436 type C**
Fabrikant Manufacturer	**Rubert**
Type Type	**528 RS-5**
Serienummer Serial number	**P1167**
Rekvirent Customer	**Institut for Produktion og Ledelse Produktionstorvet, bygn. 425 2800 Lyngby**

Dato for modtagelse Date of receipt	**19.06.07**	Dato for certifikatets udstedelse Date of issue of certificate	**24.07.07**
Dato for kalibreringen Date of calibration	**19.06.07**		

Underskrift
Signature

Jan L. Andreasen
Fagligt ansvarlig
Signatory, Surface Roughness Calibration

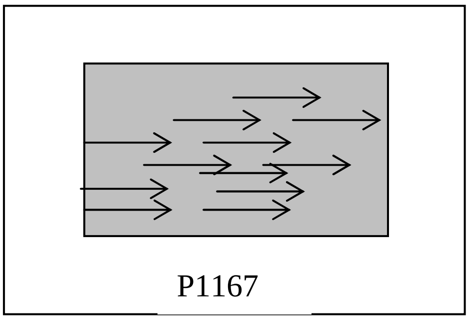
CENTER FOR GEOMETRISK METROLOGI
CGM Aps reg. nr. 203.012 CVR-nr. 15498544
Danmarks Tekniske Universitet, Bygning 425, 2800 Lyngby
Telefon 45 93 44 41 – Telefax 45 93 01 90

Kalibreringsresultater og –usikkerheder.

I den efterfølgende tabel er parameterværdier i henhold til ISO 4287-1997 og DIN 4768 angivet. Angivelserne er et gennemsnit af 12 målinger foretaget tilfældigt fordelt på overfladen. Usikkerheden er angivet med faktor k=2 ≈ 95 % konfidensniveau.

Calibration results and uncertainties.

The table below gives the roughness parameters according to ISO 4287-1997 and DIN 4768. The stated values refer to an average of 12 tracings randomly distributed over the measuring area. The uncertainties refer to the factor k=2 ≈ 95 % confidence level.



ISO parametre	DIN parametre	Fasekorrekt filter Phase correct filter	2RC-filter	Usikkerhed Uncertainty
Ra	R_a	**0.507**	**0.506**	0.013
Rz	R_z	**1.607**	**1.605**	0.040
Rz1maks	R_{max}	**1.625**	**1.627**	0.041
		µm	µm	µm

Målebetingelser.

Målingerne er udført med et fritastsystem ifølge procedure RU-534. Tastradius er ca. 2 µm. Målingerne er foretaget ved en temperatur på 20 ± 1°C. Den anvendte software er RCS4G kalibreringssoftware version 2.2. Der er anvendt Ls cut-off 2.5 µm og Lc cut-off filter på 0.8 mm og en evalueringslængde på 4.0 mm.

Measuring conditions.

The measurements were carried out by means of a pick-up system with independent datum in accordance with procedure RU-534. The stylus radius is approx. 2 µm. The measurements were carried out at a temperature of 20 ± 1°C. The software used is RCS4G calibration software Version 2.2. A Ls cut-off filter of 2.5 µm and a Lc cut-off filter of 0.8 mm were used. The evaluation length was 4.0 mm.

Måledata.

Normalen er målt efter tastsnitmetoden i 12 snit fordelt over målefladen. Den følgende tabel giver parameter værdierne for de 12 aftastninger.

Measuring data.

The standard has been measured using the tracing method in 12 traces distributed over the measuring surface. The table below gives the parameter values for the 12 traces.

	Fasekorrekt filter Phase correct filter			2RC-filter		
ISO DIN	Ra R_a	Rz R_z	Rz1maks R_{max}	Ra R_a	Rz R_z	Rz1maks R_{max}
1	0.509	1.622	1.634	0.508	1.613	1.625
2	0.506	1.609	1.663	0.506	1.606	1.654
3	0.510	1.598	1.611	0.510	1.595	1.611
4	0.504	1.597	1.622	0.504	1.601	1.626
5	0.508	1.608	1.618	0.508	1.603	1.613
6	0.508	1.610	1.623	0.508	1.606	1.626
7	0.505	1.603	1.618	0.504	1.600	1.612
8	0.506	1.605	1.613	0.506	1.604	1.609
9	0.509	1.608	1.622	0.508	1.606	1.636
10	0.506	1.610	1.619	0.506	1.604	1.626
11	0.508	1.615	1.640	0.508	1.616	1.649
12	0.500	1.595	1.613	0.500	1.602	1.634

Sporbarhed.
Traceability.

Kalibreringen er sporbar til:
The calibration is traceable to: **PTB**

Kalibreringen er sporbar via normalen:
The calibration is traceable through the standard: **HALLE no. 826**

Med certifikatet:
With the certificate: **049 PTB 04**

Certifikatet er dateret:
The certificate is dated: **11.10.04**

Vilkår for certifikatet
Conditions for the certificate

DANAK

Den Danske Akkrediterings- og Metrologifond -DANAK- administrerer den danske akkrediteringsordning på grundlag af en aftale med Sikkerhedsstyrelsen under Økonomi- og Erhvervsministeriet, som er ansvarlig for lovgivningen om akkreditering i Danmark.

De grundlæggende akkrediteringskriterier er beskrevet i henholdsvis DS/EN ISO/IEC 17025 "Generelle krav til prøvnings- og ka1ibreringslaboratoners kompetence" og i DS/EN ISO 15189 "Medicinske laboratorier- Særlige krav til kva1itet og kompetence". DANAK anvender fortolkningsdokumenter til de enkelte krav i standarderne, hvor det skønnes nødvendigt. Disse vil hovedsageligt være udarbejdet af "European co-operation for Accreditation (EA)" eller "Internationa1 Laboratory Accreditation Co-operation (ILAC)" med det formå1 at opnå ensartede kriterier for akkreditering på verdensplan. Sikkerhedsstyrelsen udsteder desuden tekniske forskrifter udarbejdet af DANAK vedr. specifikke krav til akkreditering, som ikke er indeholdt i standarderne.

For at et laboratorium kan være akkrediteret kræves blandt andet:

- at laboratoriet og dets personale skal være fri for enhver kommerciel, økonomisk eller anden form for pression, som kan påvirke deres uvildighed,
- at laboratoriet har et dokumenteret ledelsessystem og en ledelse, der kan sikre, at dette følges og vedligeholdes,
- at laboratoriet råder over teknisk udstyr og lokaler af en tilstrækkelig standard til at kunne udføre den ydelse, som laboratoriet er akkrediteret til,
- at laboratoriet råder over personale med såvel faglig kompetence som praktisk erfaring i udførelsen af de ydelser, som laboratoriet er akkrediteret til,
- at der er indarbejdet faste rutiner for sporbarhed og usikkerhedsbestemmelse,
- at akkrediteret prøvning, kalibrering eller medicinsk undersøgelse udføres efter fuldt validerede og dokumenterede metoder,
- at akkrediterede ydelser udføres og rapporteres i fortrolighed med rekvirenten og i overensstemmelse med dennes behov,
- at laboratoriet skal registrere forløbet af akkrediteret prøvning, kalibrering eller medicinsk undersøgelse således, at dette kan rekonstrueres,
- at laboratoriet er underkastet regelmæssigt tilsyn af DANAK,
- at laboratoriet skal have en forsikring, som kan dække laboratoriets ansvar i forbindelse med udførelsen af akkrediterede ydelser.

Rapporter, der bærer DANAK's akkrediteringsmærke, anvendes ved rapportering af akkrediterede ydelser og viser, at disse er foretaget i henhold til akkrediteringsreglerne.

DANAK

The Danish Accreditation and Metrology Fund -DANAK -is managing the Danish accreditation scheme based on a contract with the Danish Safety Technology Authority under the Danish Ministry of Economics and Business Affairs who is responsible for the legislation on accreditation in Denmark.

The fundamental criteria for accreditation are described in DS/EN ISO/IEC 17025: "General requirements for the competence of testing and calibration laboratories", and in DS/EN ISO/IEC 15189 "Medical laboratories -Particular requirements for quality and competence" respectively. DANAK uses guidance documents to clarify the requirements in the standards, where this is considered to be necessary.. These will mainly be drawn up by the "European co-operation for Accreditation (EA)" or the "International Laboratory Accreditation Co-operation (ILAC)" with a view to obtaining uniform criteria for accreditation worldwide. In addition, the Danish Safety Technology Authority issues Technical Regulations prepared by DANAK with specific requirements for accreditation that are not contained in the standards.

In order for a laboratory to be accredited it is, among other things, required:

- that the laboratory and its personnel are free from any commercial, financial or other pressures, which might influence their impartiality;
- that the laboratory operates a documented management system, and has a management that ensures that the system is followed and maintained;
- that the laboratory has at its disposal all items of equipment, facilities and premises required for correct performance of the service that it is accredited to perform;
- that the laboratory has at its disposal personnel with technical competence and practical experience in performing the services that they are accredited to perform;
- that the laboratory has procedures for traceability and uncertainty calculations;
- that accredited testing, calibration or medical examination are performed in accordance with fully validated and documented methods;
- that accredited services are performed and reported in confidentiality with the customer and in compliance with the customer’s request;
- that the laboratory keeps records which contain sufficient information to permit repetition of the accredited test, calibration or medical examination;
- that the laboratory is subject to surveillance by DANAK on a regular basis;
- that the laboratory shall take out an insurance, which covers liability in connection with the performance of accredited services.

Reports carrying DANAK' s accreditation mark are used when reporting accredited services and show that these have been performed in accordance with the rules for accreditation.

Appendix J

Surface roughness profiles in their original format

Appendix J contains profiles from all the operators (i.e. E, A, B, C, D, F, G). The instrument was Surtronic 4+, Taylor Hobson.

Four profiles on each page correspond to four profiles taken around the hole circumference.

P: Low speed, 4.5 m/min
R: High speed, 10.2 m/min

Feed, 0.3 mm/rev (operators A, B, C, D, E and F)
Feed, 0.2 mm/rev (operator G)

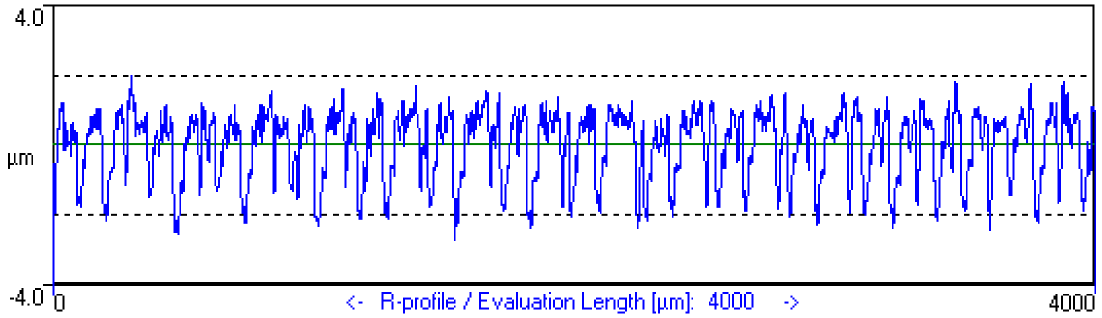
Appendix J1: Surface roughness measurement

Operator E: 23/03-2010

Operator E – 23/03 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P1 – 1% oil concentration (P0.3/W1)

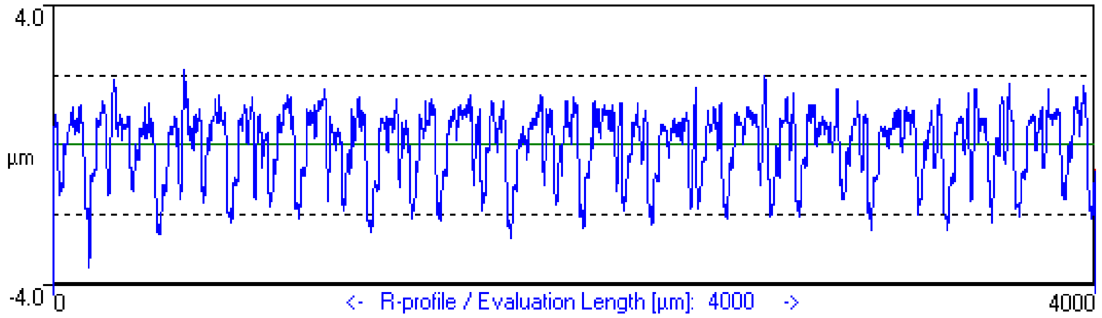
File: P1_1%.dat.dat Profile no.: 1 Specimenmark: 0393341 5/26/2010



Ra 0.834
Rz 4.162

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

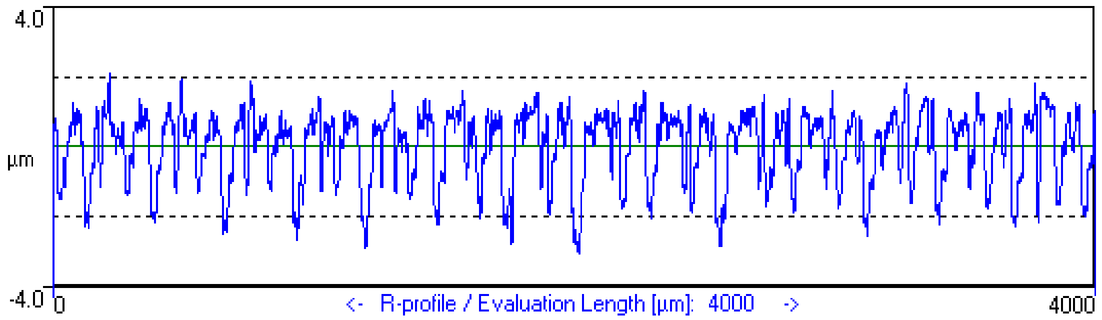
File: P1_1%.dat.dat Profile no.: 2 Specimenmark: 0393341 5/26/2010



Ra 0.834
Rz 4.484

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

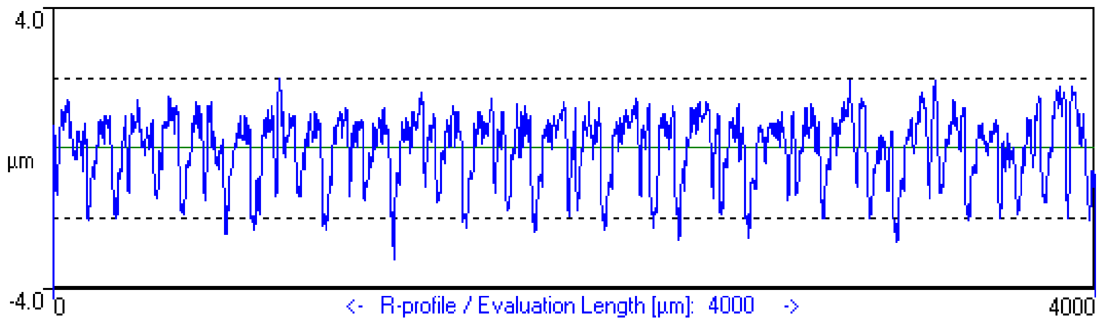
File: P1_1%.dat.dat Profile no.: 3 Specimenmark: 0393341 5/26/2010



Ra 0.856
Rz 4.442

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: P1_1%.dat.dat Profile no.: 4 Specimenmark: 0393341 5/26/2010



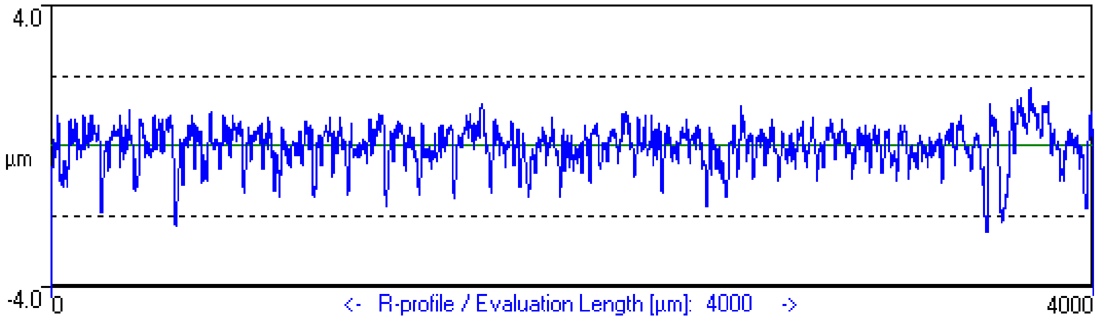
Ra 0.799
Rz 4.404

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

Operator E – 23/03 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P2 – 1% oil concentration (P0.3/W1)

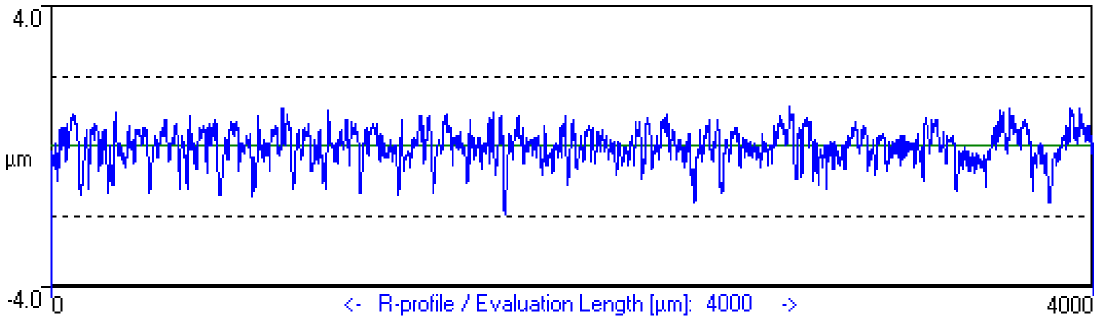
File: P2_1%.dat.dat Profile no.: 1 Specimenmark: 0393341 5/26/2010



Ra 0.424
Rz 3.108

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

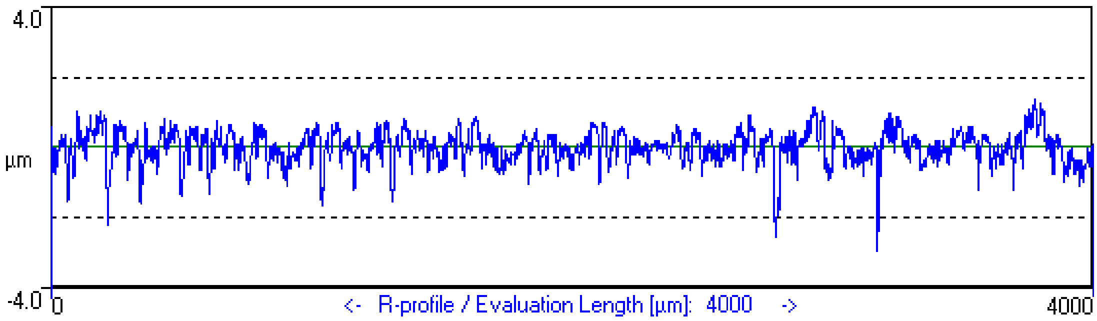
File: P2_1%.dat.dat Profile no.: 2 Specimenmark: 0393341 5/26/2010



Ra 0.377
Rz 2.642

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

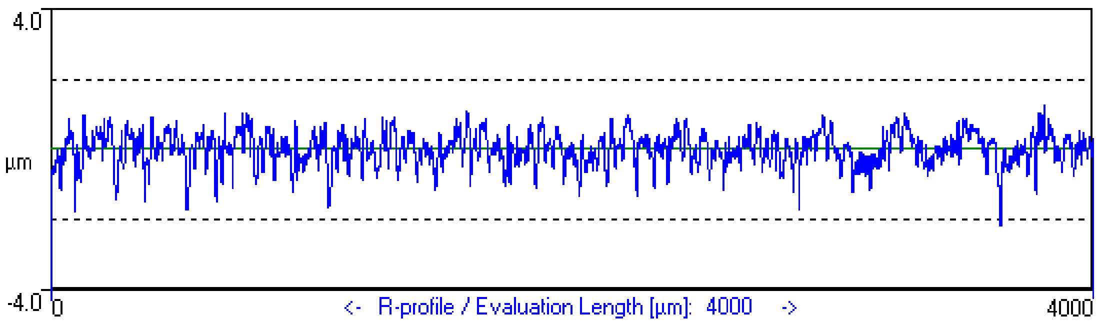
File: P2_1%.dat.dat Profile no.: 3 Specimenmark: 0393341 5/26/2010



Ra 0.362
Rz 2.850

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: P2_1%.dat.dat Profile no.: 4 Specimenmark: 0393341 5/26/2010



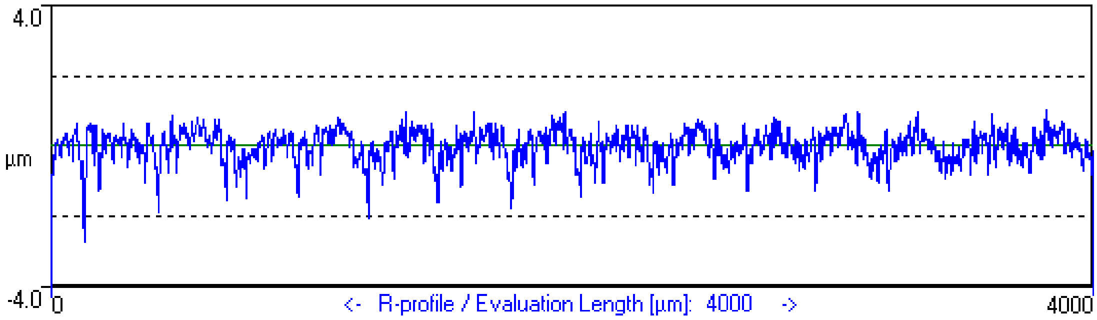
Ra 0.372
Rz 2.784

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

Operator E – 23/03 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P3 – 1% oil concentration (P0.3/W1)

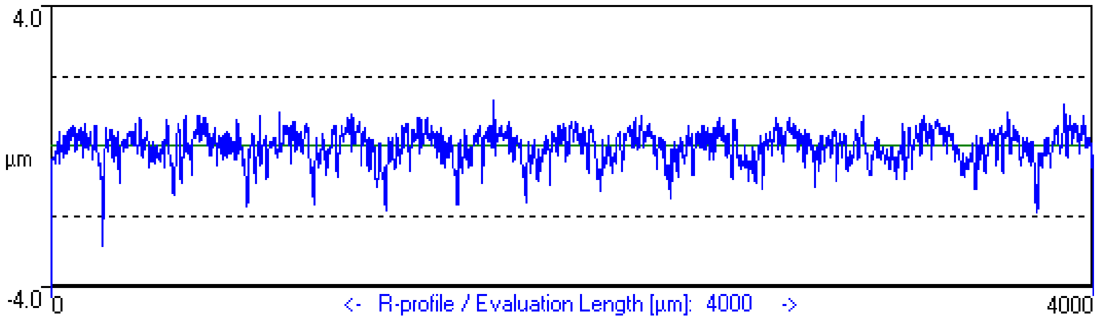
File: P3_1%.dat.dat Profile no.: 1 Specimenmark: 0393341 5/26/2010



Ra 0.340
Rz 2.778

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

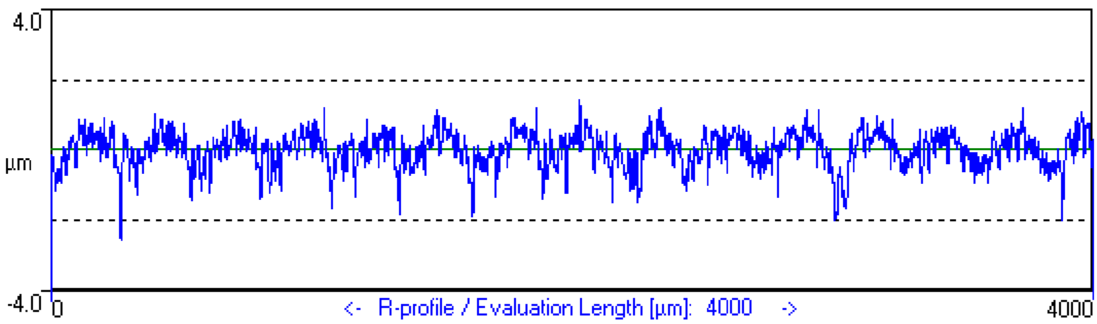
File: P3_1%.dat.dat Profile no.: 2 Specimenmark: 0393341 5/26/2010



Ra 0.354
Rz 2.922

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

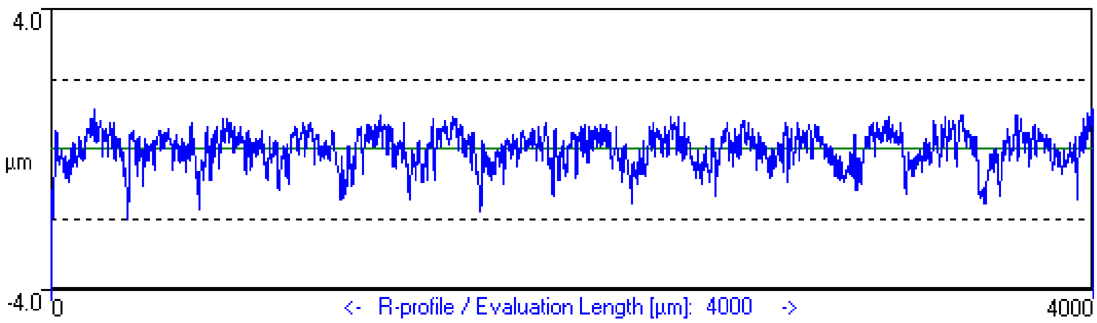
File: P3_1%.dat.dat Profile no.: 3 Specimenmark: 0393341 5/26/2010



Ra 0.398
Rz 3.234

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: P3_1%.dat.dat Profile no.: 4 Specimenmark: 0393341 5/26/2010



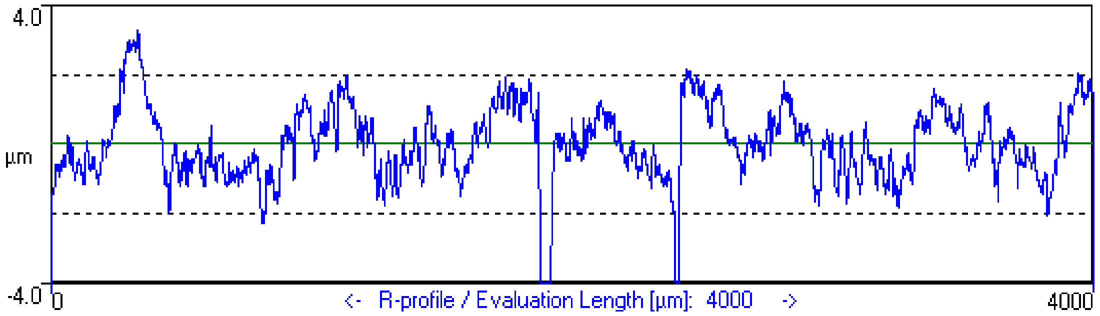
Ra 0.391
Rz 2.622

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

Operator E – 23/03 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R1 – 1% oil concentration (R0.3/W1)

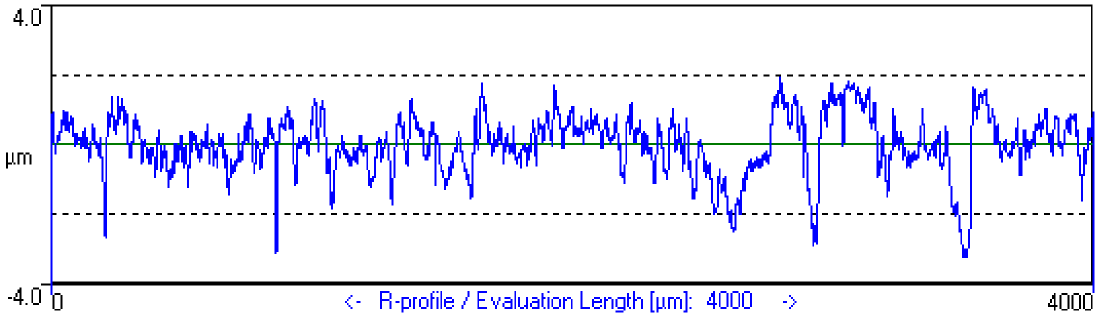
File: R1_1%.dat   Profile no.: 1   Specimenmark: 0393341   5/26/2010



Ra 0.841
Rz 5.812

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

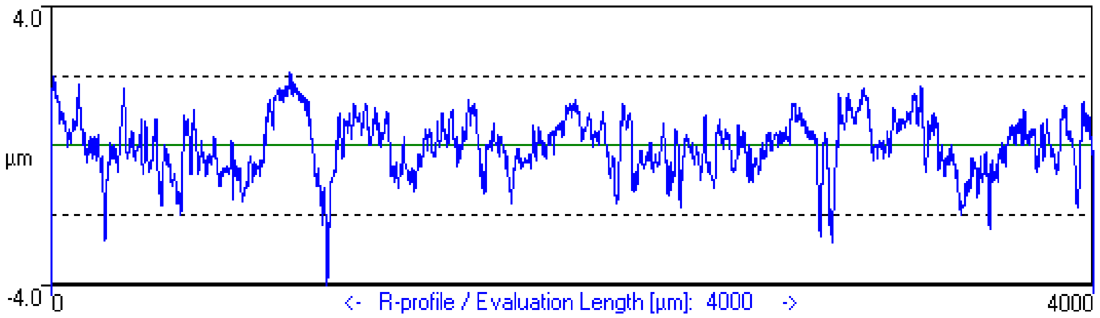
File: R1_1%.dat   Profile no.: 2   Specimenmark: 0393341   5/26/2010



Ra 0.624
Rz 4.278

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

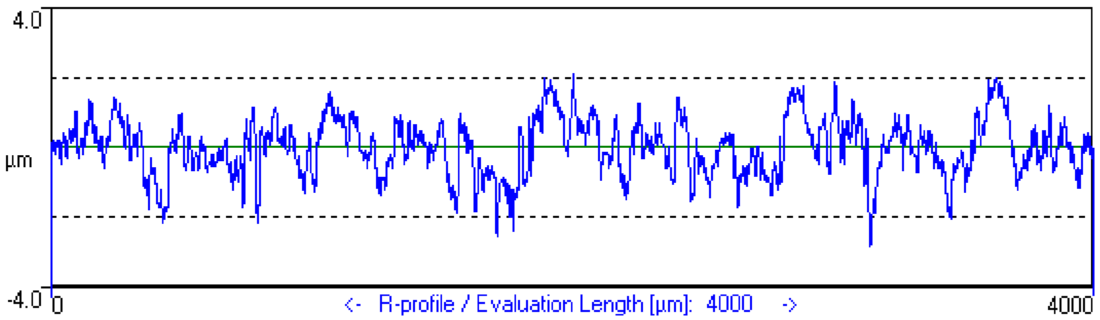
File: R1_1%.dat   Profile no.: 3   Specimenmark: 0393341   5/26/2010



Ra 0.644
Rz 4.448

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: R1_1%.dat   Profile no.: 4   Specimenmark: 0393341   5/26/2010



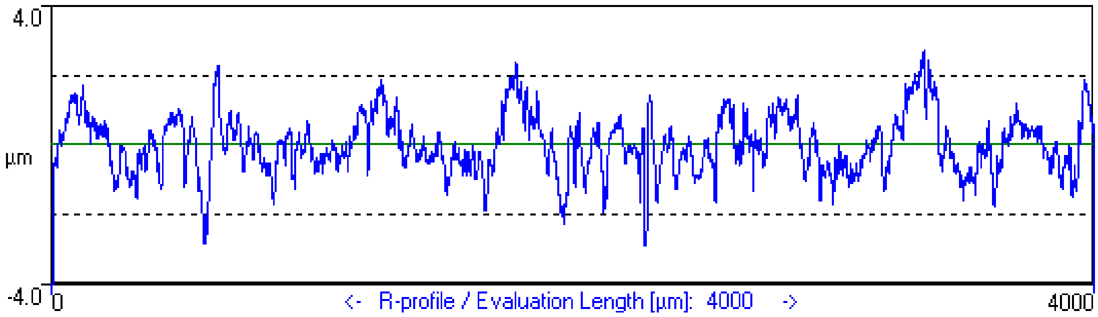
Ra 0.641
Rz 4.086

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

Operator E – 23/03 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R2 – 1% oil concentration (R0.3/W1)

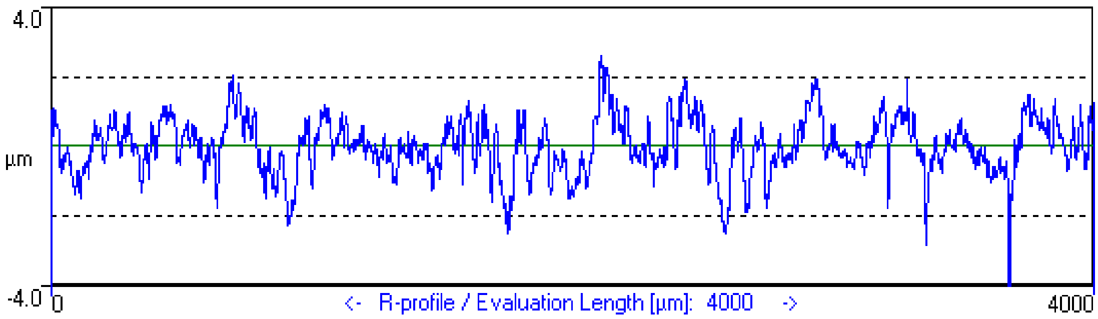
File: R2_1%.dat   Profile no.: 1   Specimenmark: 0393341   5/26/2010



Ra 0.673
Rz 5.280

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

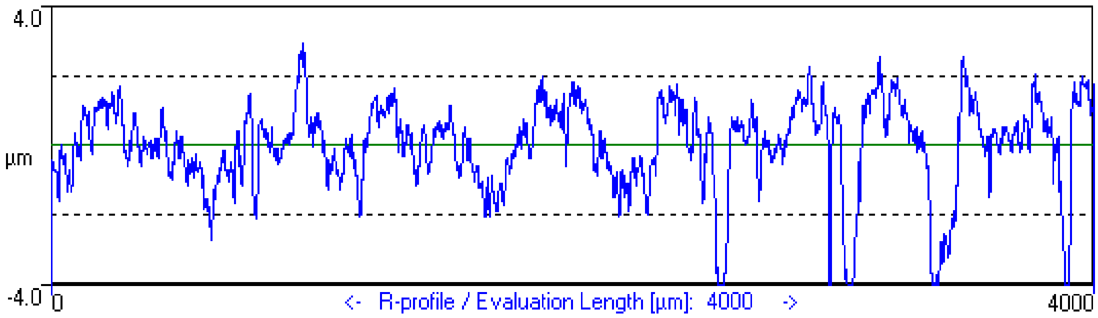
File: R2_1%.dat   Profile no.: 2   Specimenmark: 0393341   5/26/2010



Ra 0.628
Rz 4.806

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

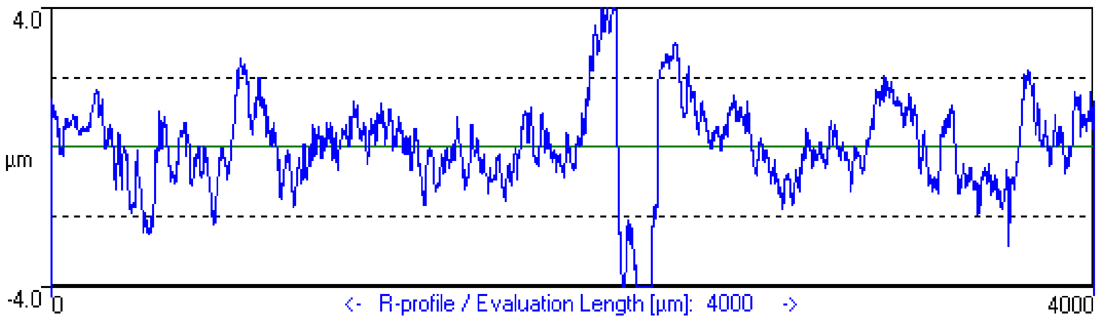
File: R2_1%.dat   Profile no.: 3   Specimenmark: 0393341   5/26/2010



Ra 0.953
Rz 5.874

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: R2_1%.dat   Profile no.: 4   Specimenmark: 0393341   5/26/2010



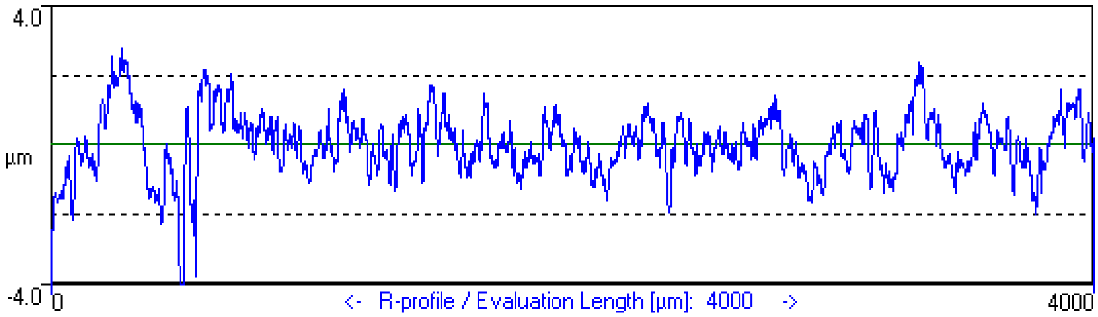
Ra 0.974
Rz 6.656

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

Operator E – 23/03 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R3 – 1% oil concentration (R0.3/W1)

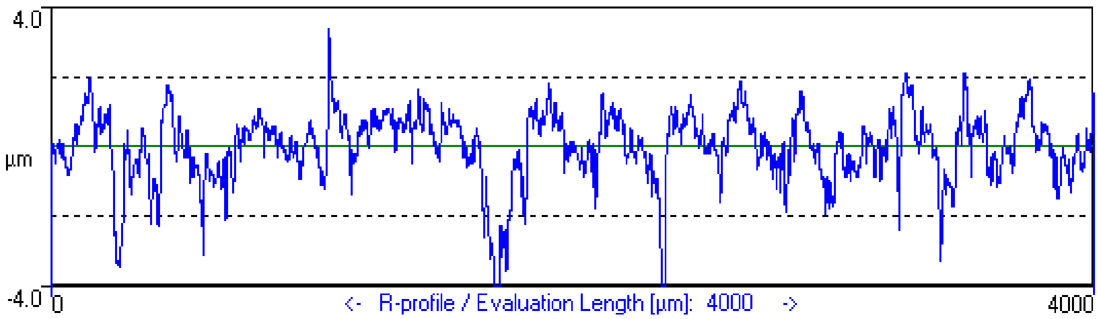
File: R3_1%.dat   Profile no.: 1   Specimenmark: 0393341   5/26/2010



Ra 0.692
Rz 4.586

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

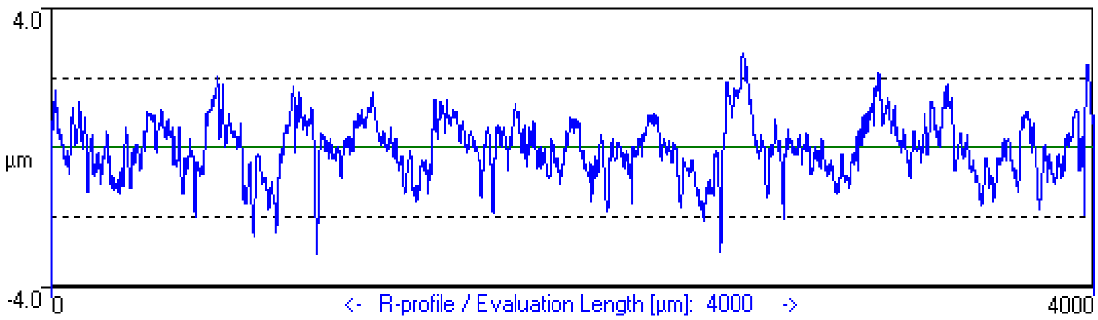
File: R3_1%.dat   Profile no.: 2   Specimenmark: 0393341   5/26/2010



Ra 0.746
Rz 5.280

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

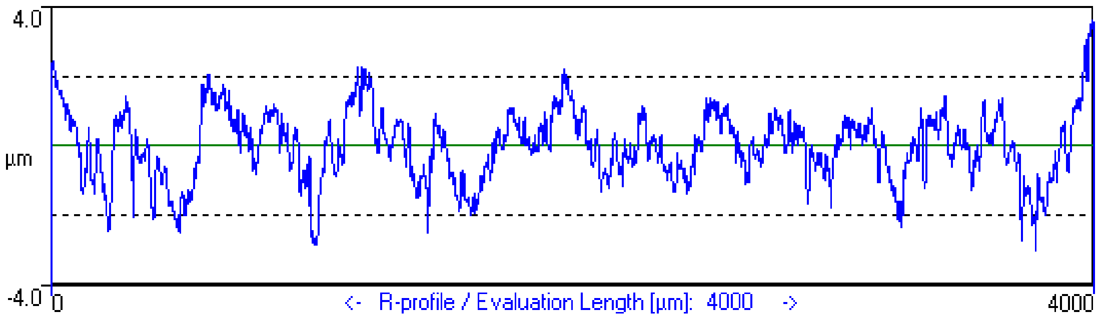
File: R3_1%.dat   Profile no.: 3   Specimenmark: 0393341   5/26/2010



Ra 0.655
Rz 4.522

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: R3_1%.dat   Profile no.: 4   Specimenmark: 0393341   5/26/2010



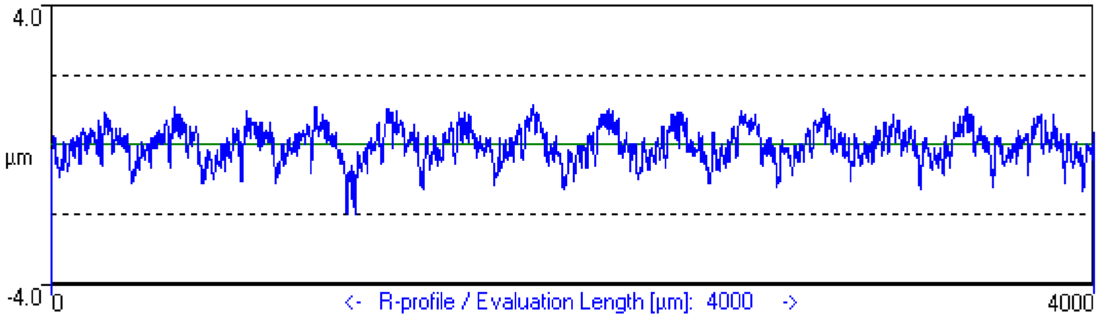
Ra 0.786
Rz 4.786

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

Operator E – 23/03 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P1 – 10% oil concentration (P0.3/W2)

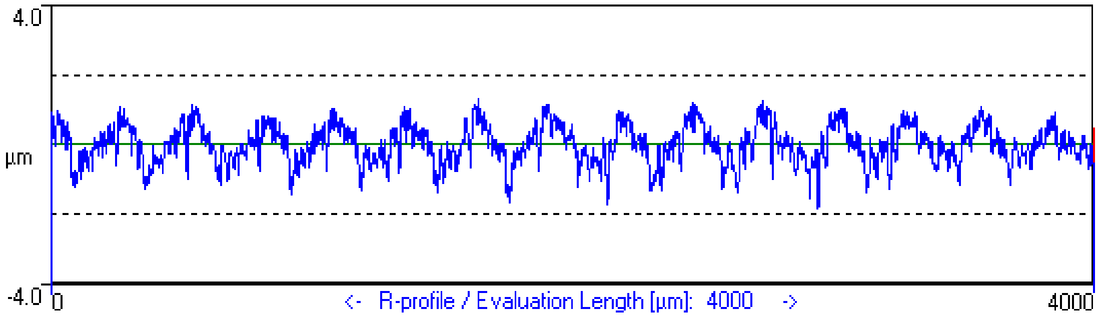
File: P1_10%.dat Profile no.: 1 Specimenmark: 0393341 5/26/2010



Ra 0.375
Rz 2.464

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

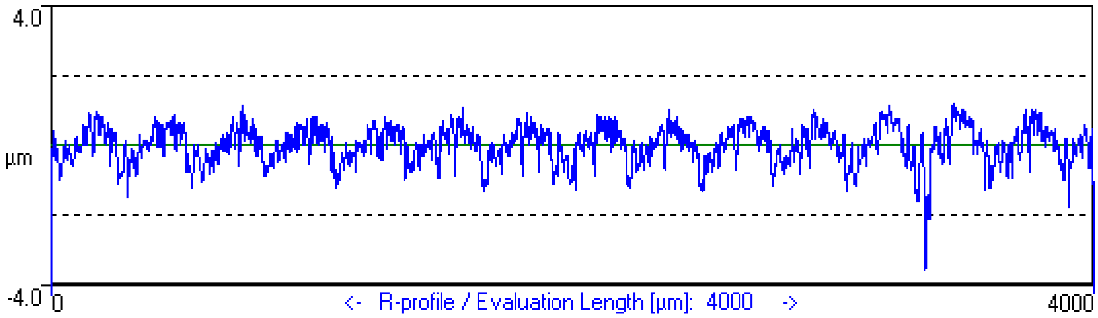
File: P1_10%.dat Profile no.: 2 Specimenmark: 0393341 5/26/2010



Ra 0.438
Rz 2.676

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

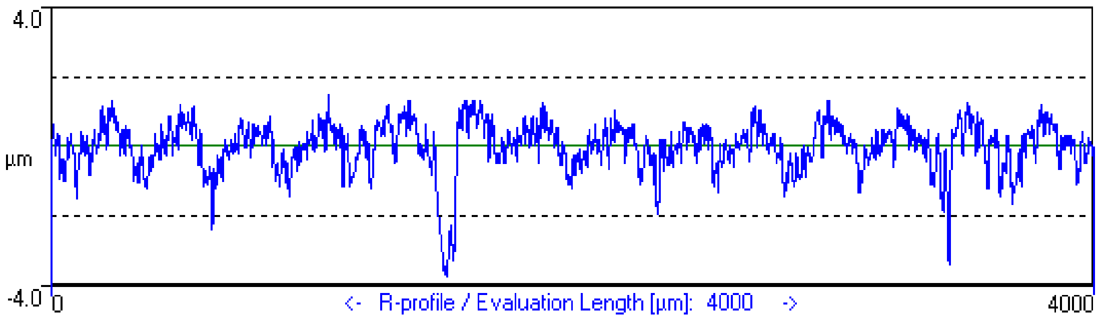
File: P1_10%.dat Profile no.: 3 Specimenmark: 0393341 5/26/2010



Ra 0.415
Rz 2.886

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: P1_10%.dat Profile no.: 4 Specimenmark: 0393341 5/26/2010



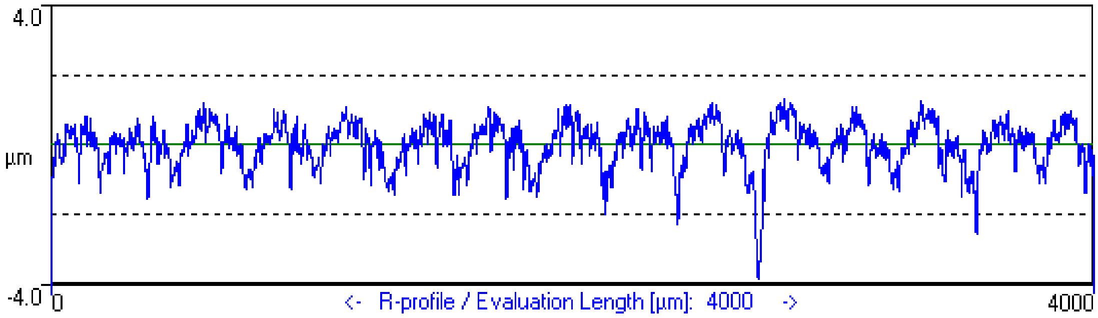
Ra 0.515
Rz 3.900

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

Operator E – 23/03 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P2 – 10% oil concentration (P0.3/W2)

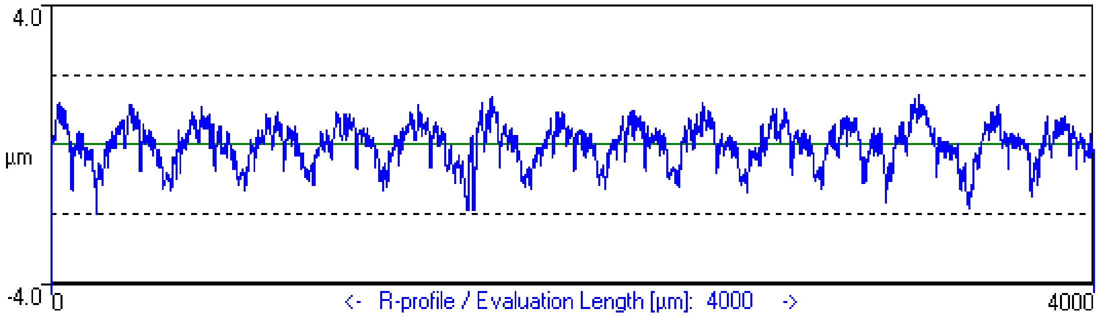
File: P2_10%.dat   Profile no.: 1   Specimenmark: 0393341   5/26/2010



Ra 0.496
Rz 3.464

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

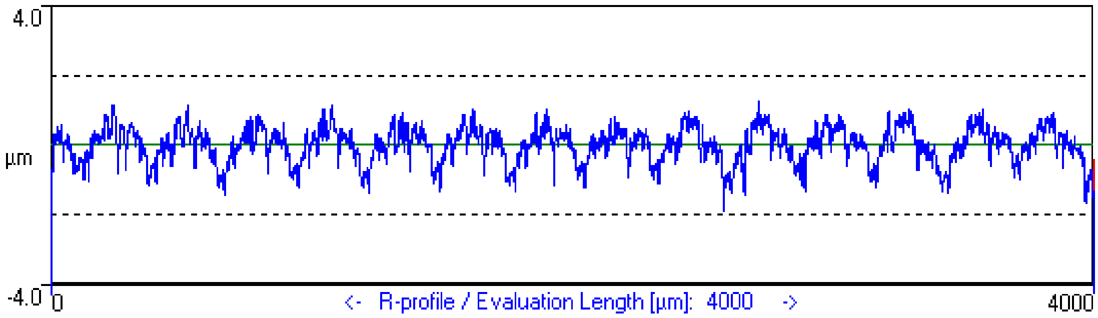
File: P2_10%.dat   Profile no.: 2   Specimenmark: 0393341   5/26/2010



Ra 0.456
Rz 3.082

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

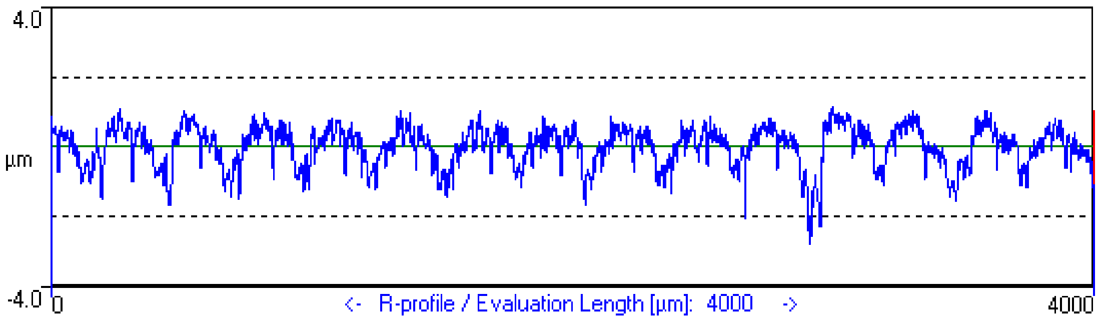
File: P2_10%.dat   Profile no.: 3   Specimenmark: 0393341   5/26/2010



Ra 0.404
Rz 2.652

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: P2_10%.dat   Profile no.: 4   Specimenmark: 0393341   5/26/2010



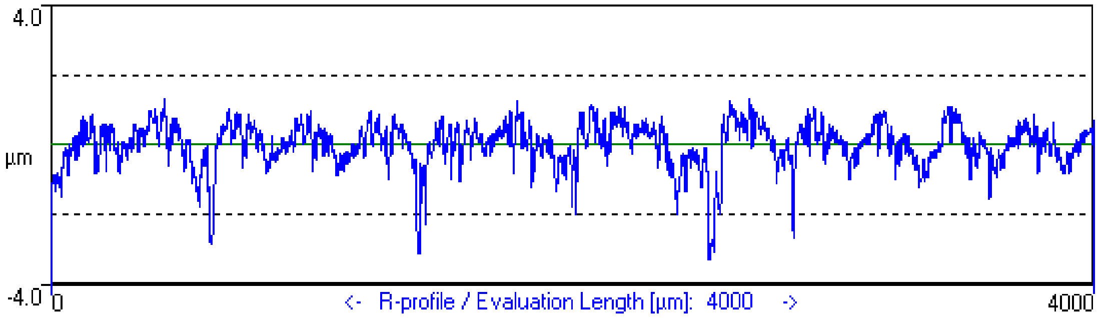
Ra 0.464
Rz 2.878

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

Operator E – 23/03 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P3 – 10% oil concentration (P0.3/W2)

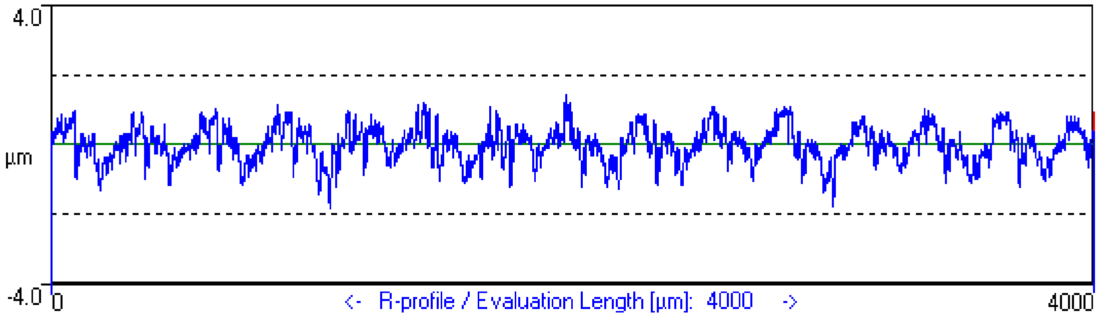
File: P3_10%.dat Profile no.: 1 Specimenmark: 0393341 5/26/2010



Ra 0.468
Rz 3.738

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

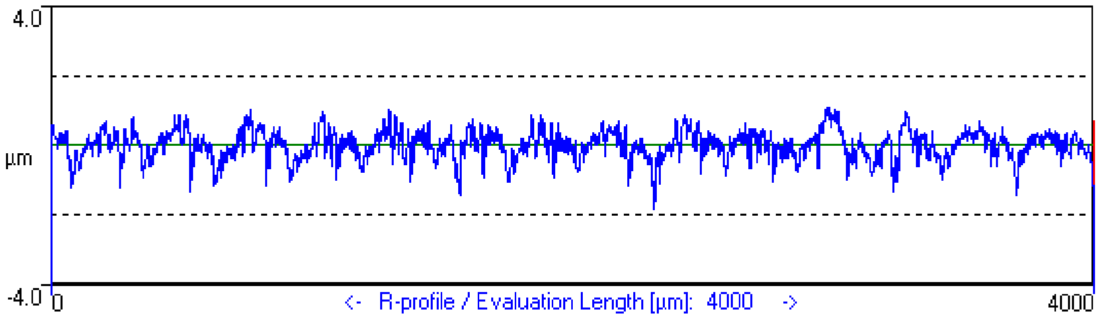
File: P3_10%.dat Profile no.: 2 Specimenmark: 0393341 5/26/2010



Ra 0.402
Rz 2.628

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

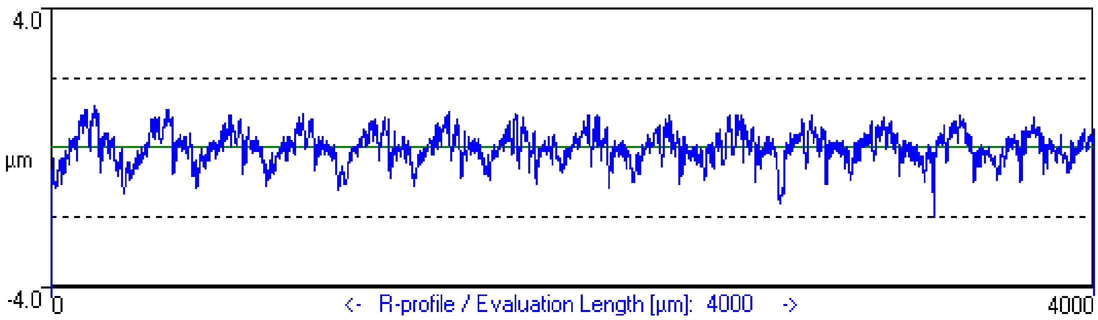
File: P3_10%.dat Profile no.: 3 Specimenmark: 0393341 5/26/2010



Ra 0.327
Rz 2.402

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: P3_10%.dat Profile no.: 4 Specimenmark: 0393341 5/26/2010



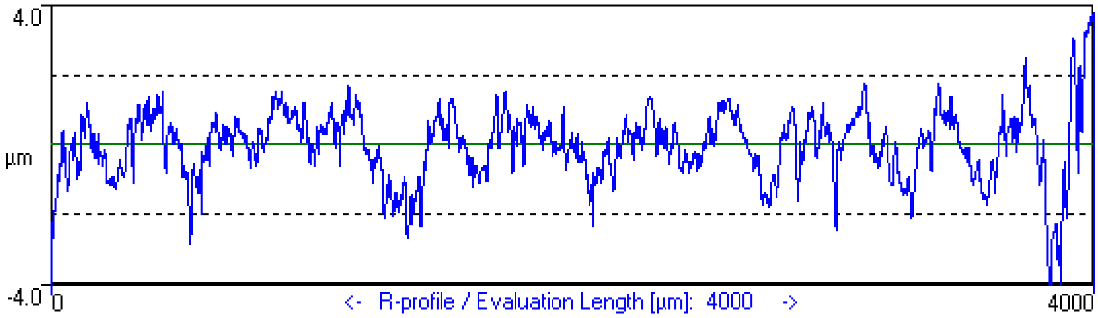
Ra 0.348
Rz 2.472

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

Operator E – 23/03 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R1 – 10% oil concentration (R0.3/W2)

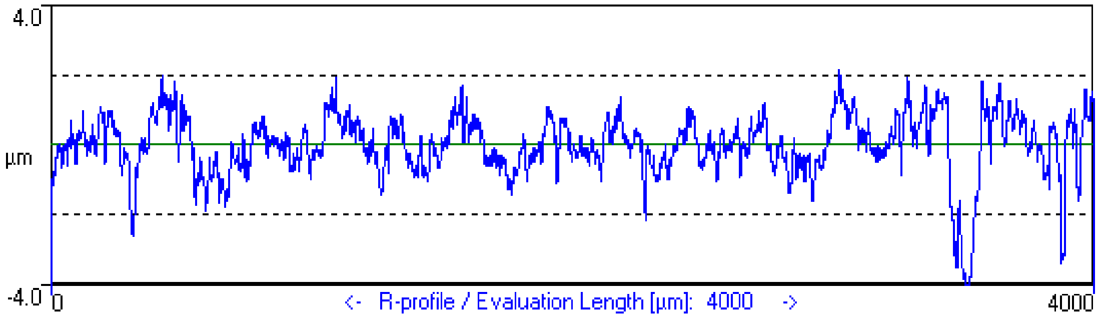
File: R1_10%.dat   Profile no.: 1   Specimenmark: 0393341   5/26/2010



Ra 0.740
Rz 4.948

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

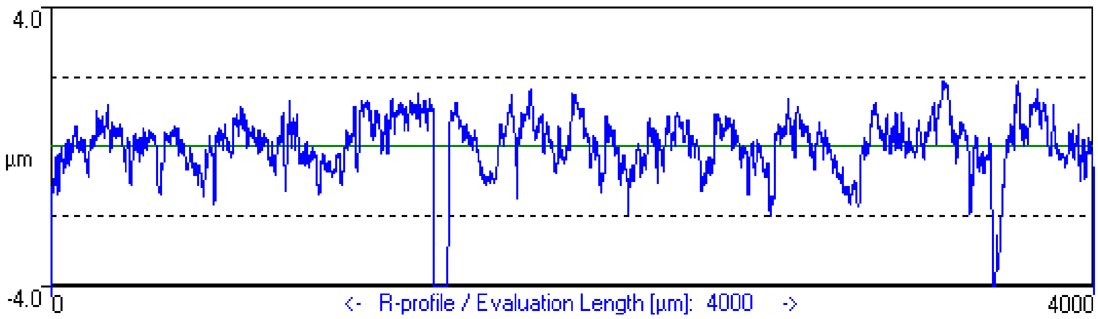
File: R1_10%.dat   Profile no.: 2   Specimenmark: 0393341   5/26/2010



Ra 0.642
Rz 4.362

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

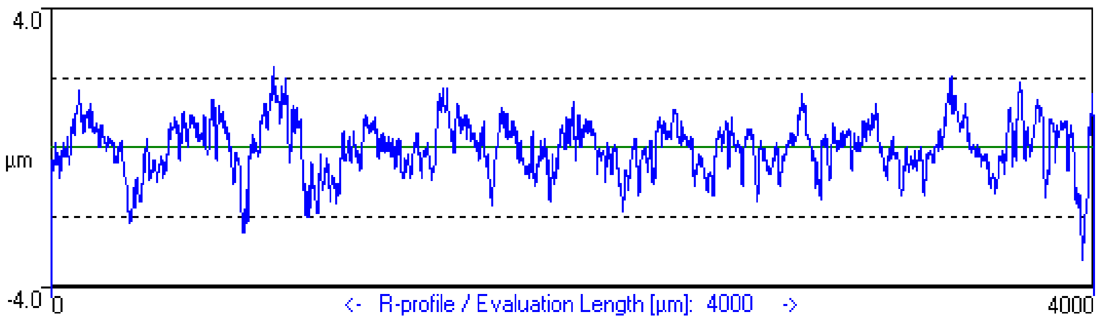
File: R1_10%.dat   Profile no.: 3   Specimenmark: 0393341   5/26/2010



Ra 0.641
Rz 4.928

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: R1_10%.dat   Profile no.: 4   Specimenmark: 0393341   5/26/2010



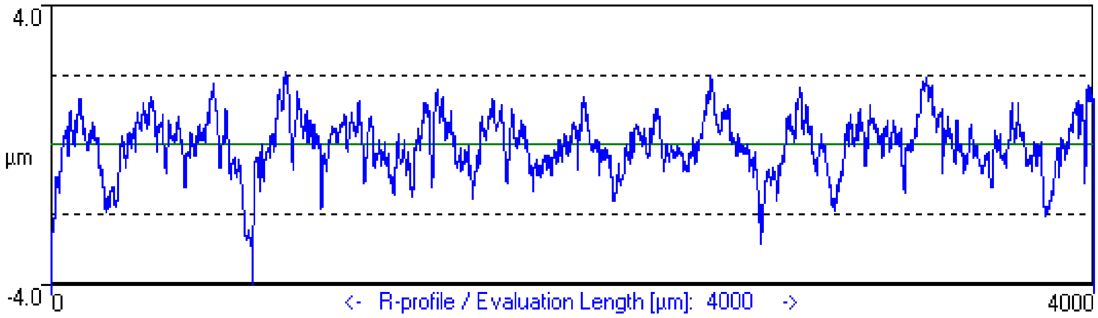
Ra 0.592
Rz 3.970

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

Operator E – 23/03 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R2 – 10% oil concentration (R0.3/W2)

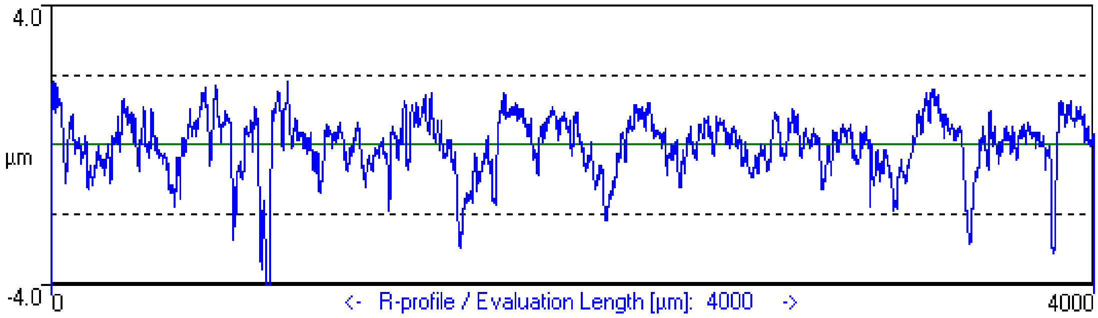
File: R2_10%.dat Profile no.: 1 Specimenmark: 0393341 5/26/2010



Ra 0.610
Rz 4.314

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

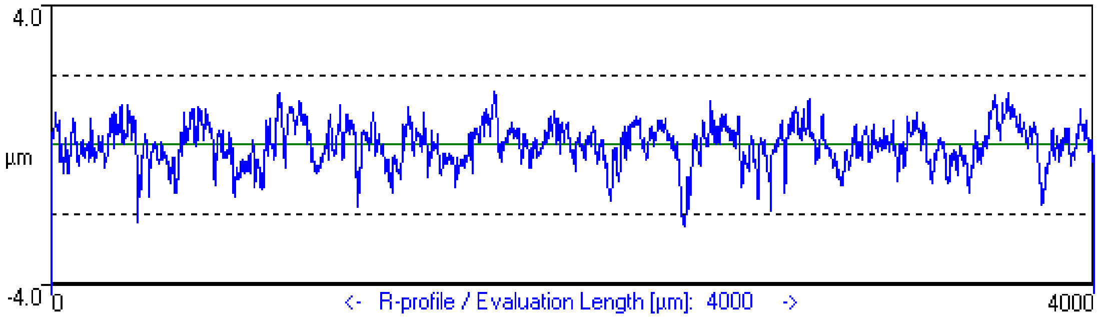
File: R2_10%.dat Profile no.: 2 Specimenmark: 0393341 5/26/2010



Ra 0.634
Rz 4.794

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

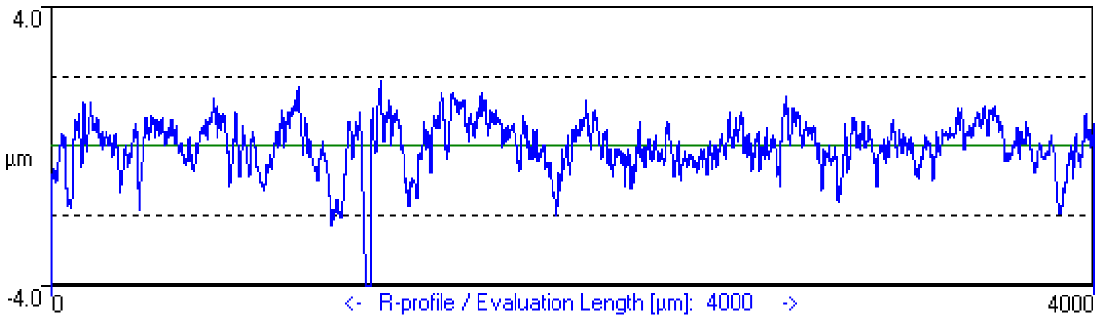
File: R2_10%.dat Profile no.: 3 Specimenmark: 0393341 5/26/2010



Ra 0.459
Rz 3.310

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: R2_10%.dat Profile no.: 4 Specimenmark: 0393341 5/26/2010



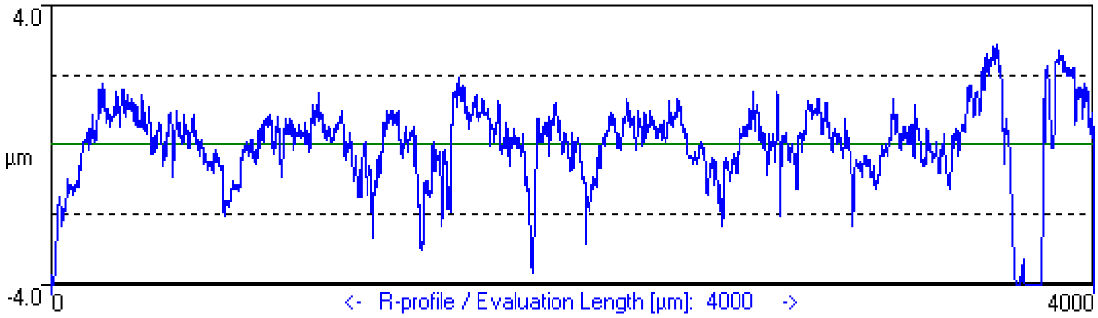
Ra 0.551
Rz 3.886

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

Operator E – 23/03 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R3 – 10% oil concentration (R0.3/W2)

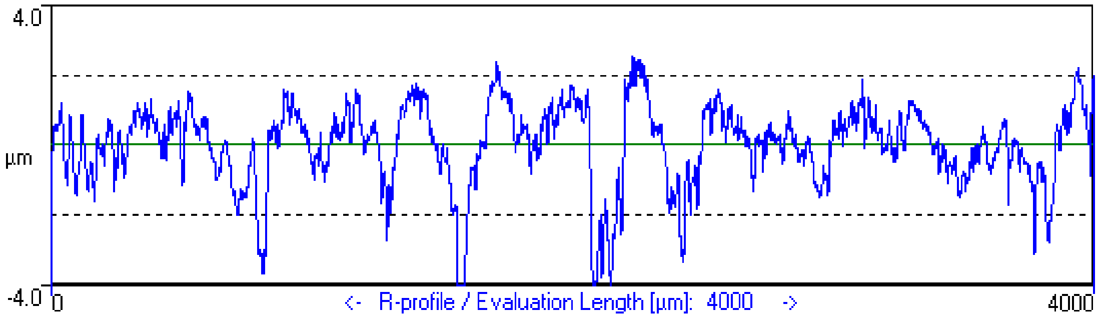
File: R3_10%.dat Profile no.: 1 Specimenmark: 0393341 5/26/2010



Ra 0.851
Rz 5.830

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

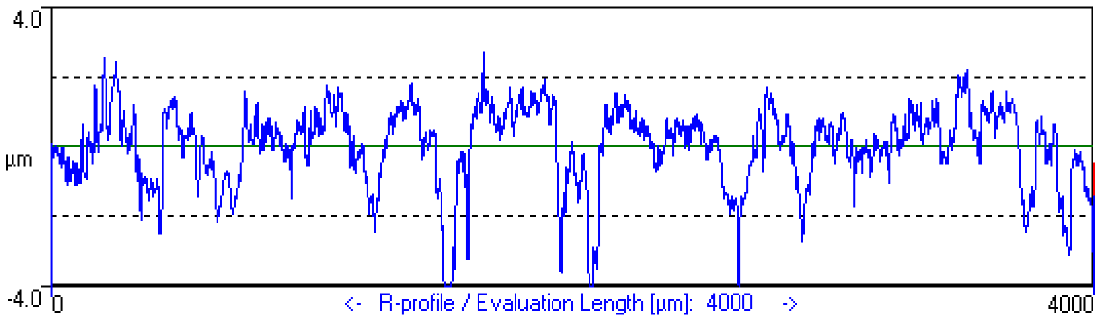
File: R3_10%.dat Profile no.: 2 Specimenmark: 0393341 5/26/2010



Ra 0.877
Rz 5.898

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

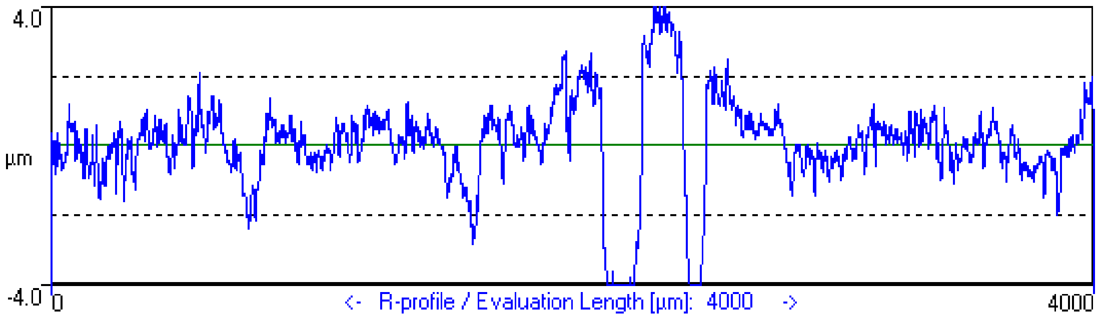
File: R3_10%.dat Profile no.: 3 Specimenmark: 0393341 5/26/2010



Ra 0.894
Rz 6.716

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: R3_10%.dat Profile no.: 4 Specimenmark: 0393341 5/26/2010



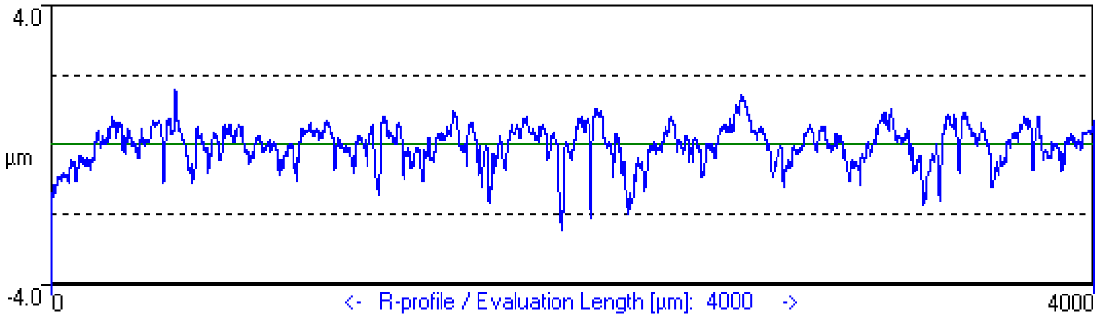
Ra 0.941
Rz 6.780

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

Operator E – 23/03 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P1 – OIL (P0.3/M)

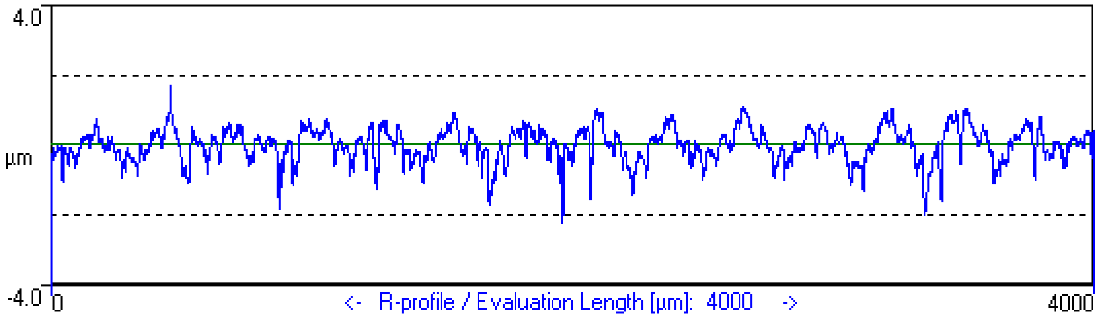
File: P1_oil.dat Profile no.: 1 Specimenmark: 0393341 5/26/2010



Ra 0.422
Rz 2.882

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

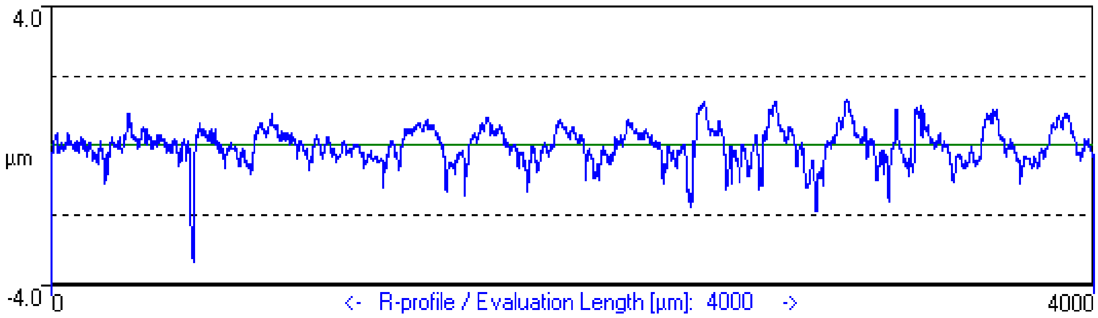
File: P1_oil.dat Profile no.: 2 Specimenmark: 0393341 5/26/2010



Ra 0.381
Rz 2.830

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

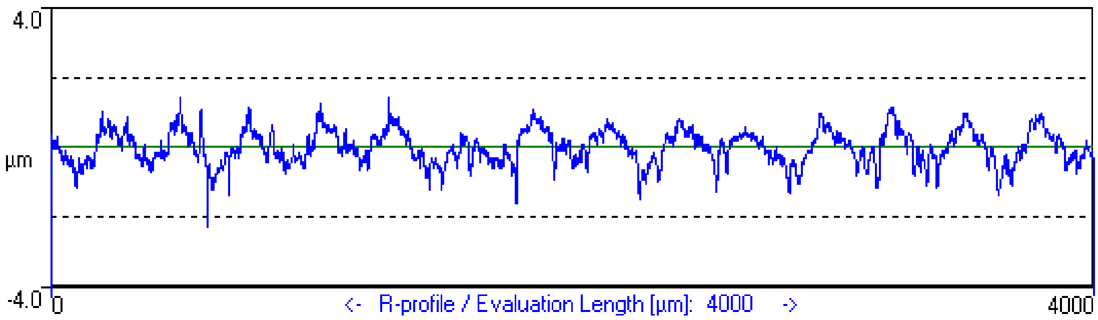
File: P1_oil.dat Profile no.: 3 Specimenmark: 0393341 5/26/2010



Ra 0.384
Rz 2.944

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: P1_oil.dat Profile no.: 4 Specimenmark: 0393341 5/26/2010



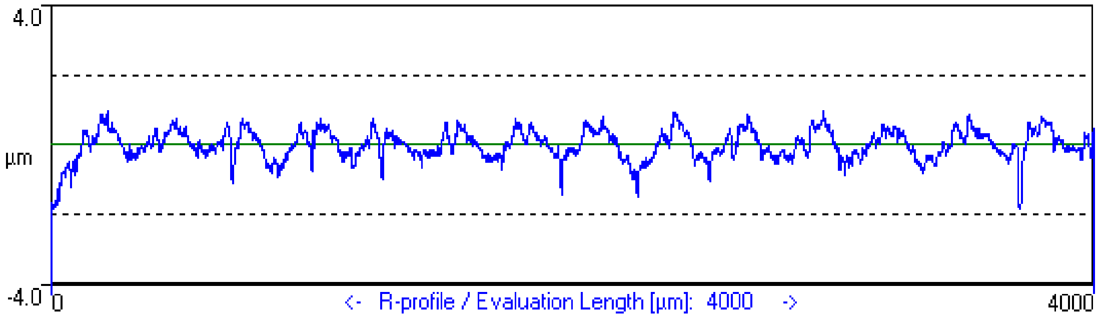
Ra 0.394
Rz 2.760

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

Operator E – 23/03 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P2 – OIL (P0.3/M)

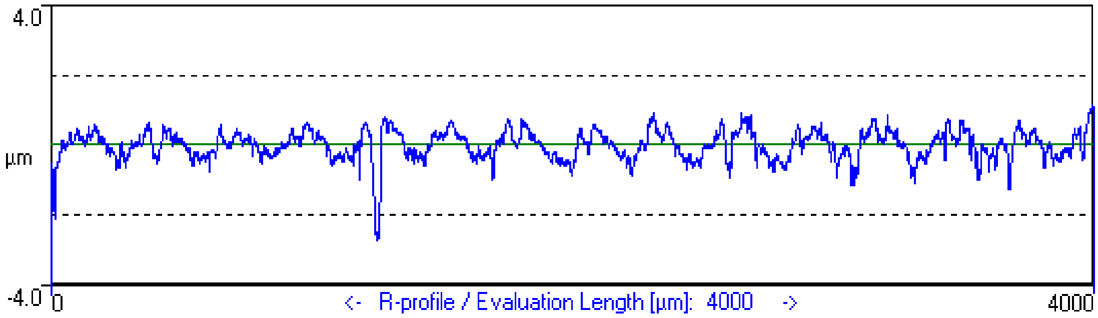
File: P2_oil.dat Profile no.: 1 Specimenmark: 0393341 5/26/2010



Ra 0.339
Rz 2.318

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

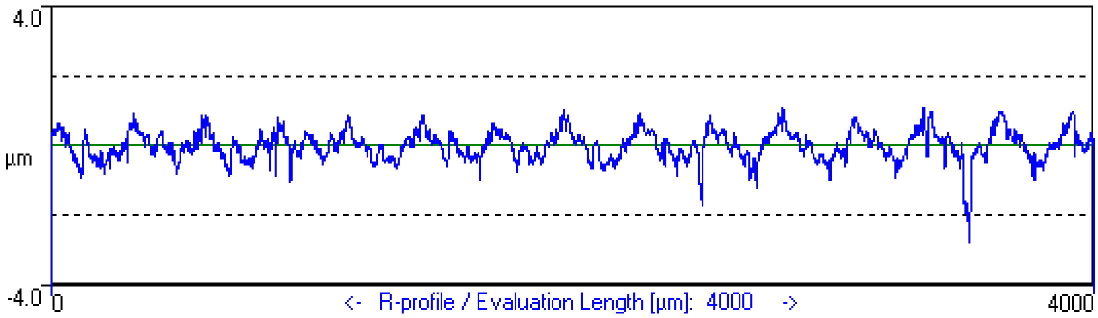
File: P2_oil.dat Profile no.: 2 Specimenmark: 0393341 5/26/2010



Ra 0.328
Rz 2.532

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

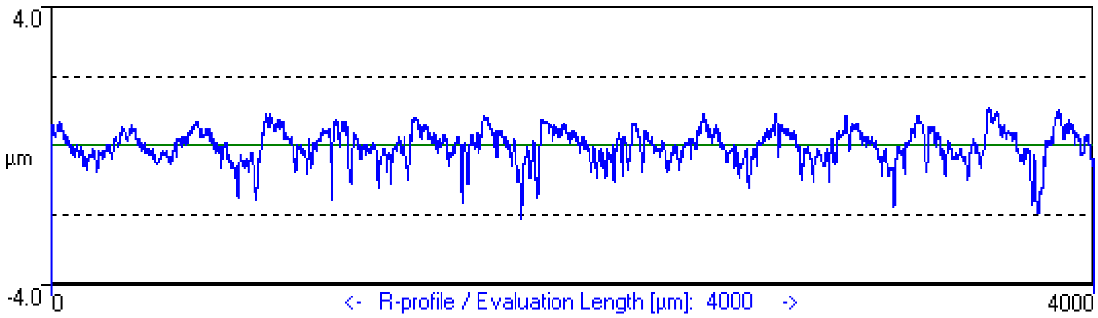
File: P2_oil.dat Profile no.: 3 Specimenmark: 0393341 5/26/2010



Ra 0.331
Rz 2.480

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: P2_oil.dat Profile no.: 4 Specimenmark: 0393341 5/26/2010



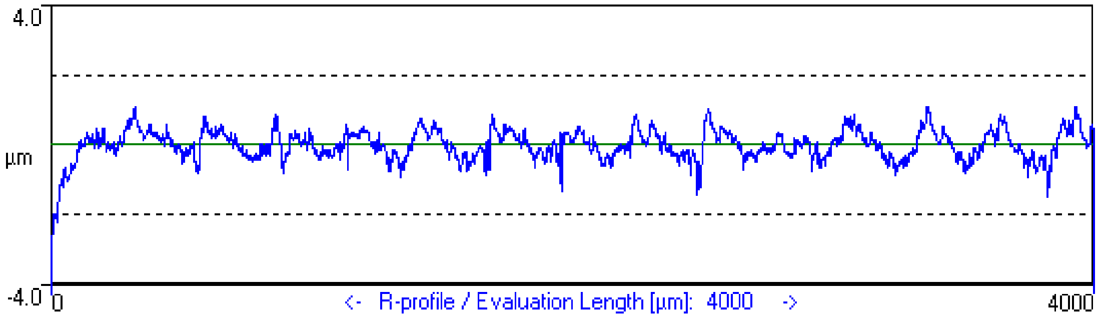
Ra 0.365
Rz 2.592

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

Operator E – 23/03 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P3 – OIL (P0.3/M)

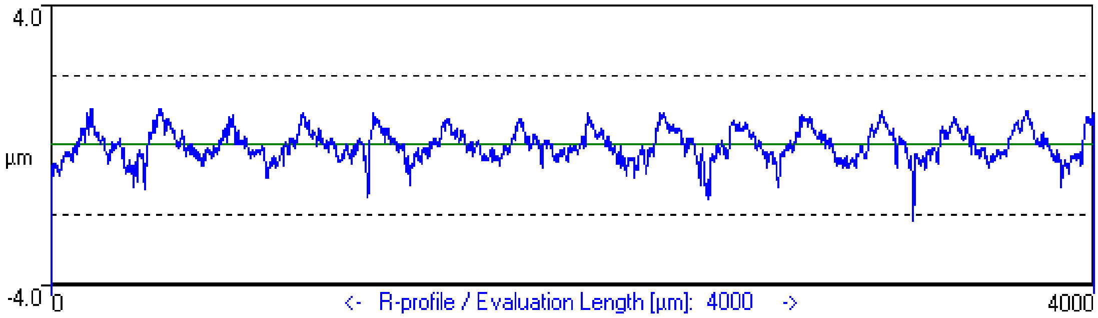
File: P3_oil.dat Profile no.: 1 Specimenmark: 0393341 5/26/2010



Ra 0.331
Rz 2.600

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

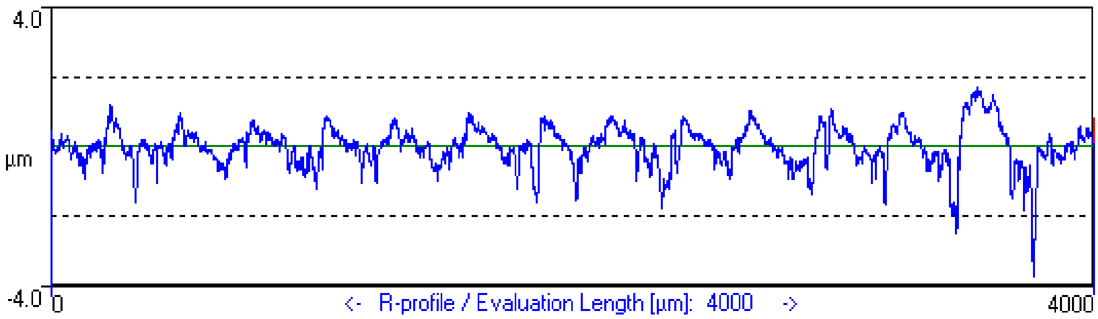
File: P3_oil.dat Profile no.: 2 Specimenmark: 0393341 5/26/2010



Ra 0.348
Rz 2.446

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

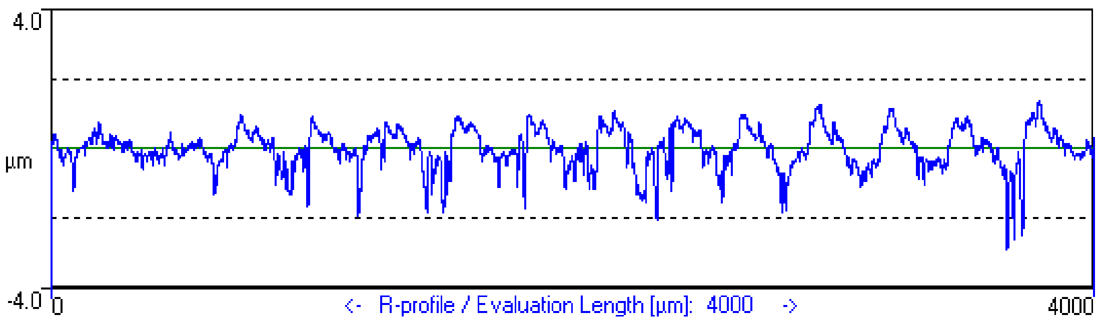
File: P3_oil.dat Profile no.: 3 Specimenmark: 0393341 5/26/2010



Ra 0.427
Rz 3.178

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

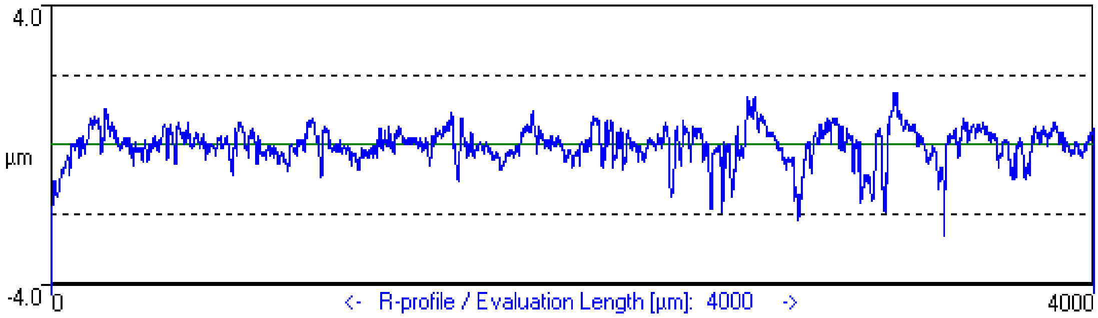
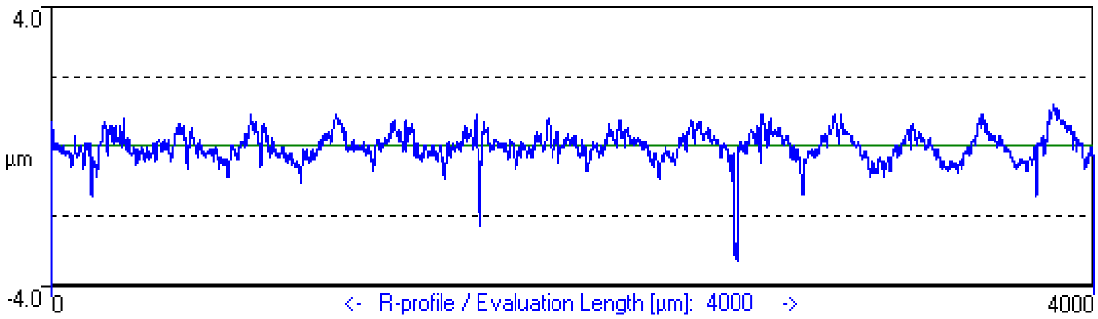
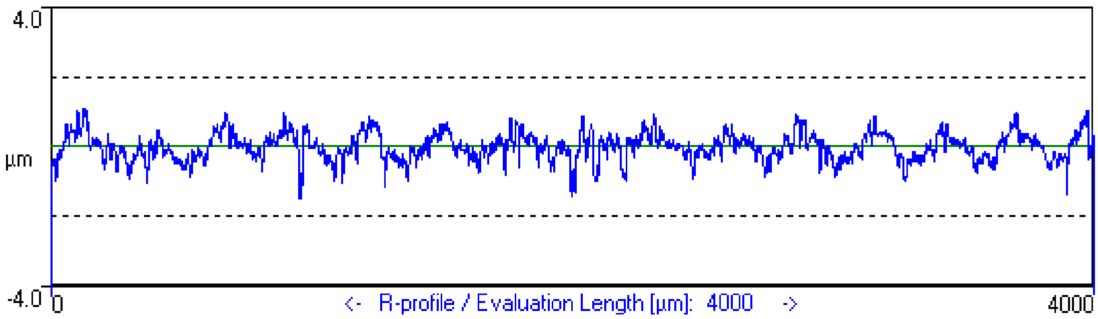
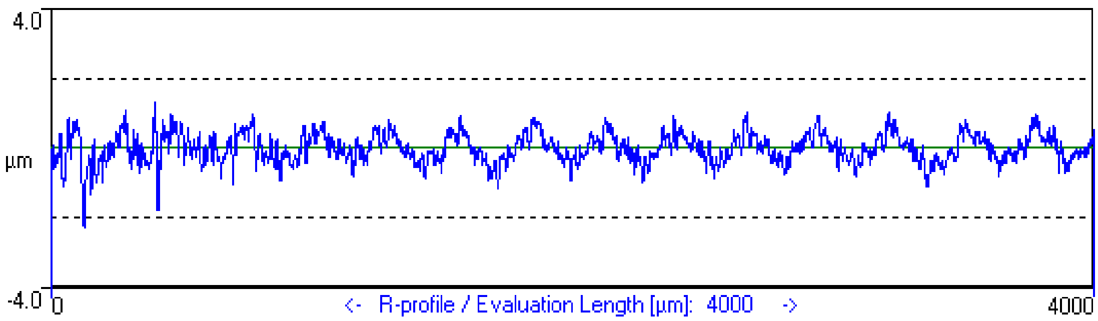
File: P3_oil.dat Profile no.: 4 Specimenmark: 0393341 5/26/2010



Ra 0.442
Rz 3.118

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

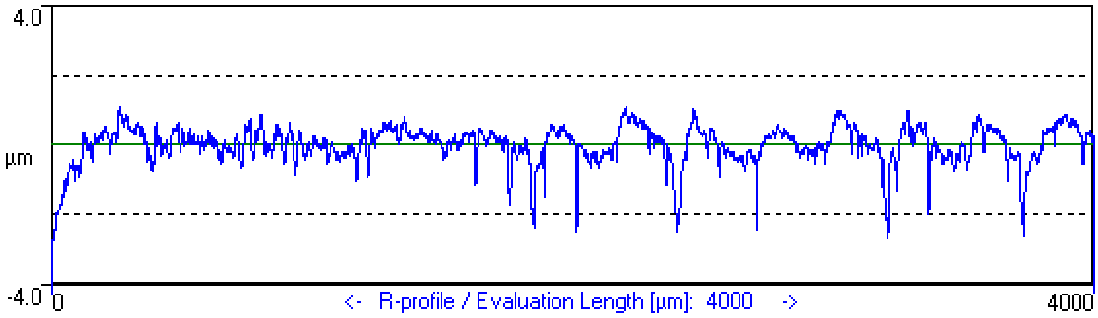
Operator E – 23/03 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R1 – OIL (R0.3/M)
File: R1_oil.dat Profile no.: 1 Specimenmark: 0393341 5/26/2010  Ra 0.361 Rz 3.138 Form removal : None Ls filter cut-off : 0.0 Lc filter cut-off : 800
File: R1_oil.dat Profile no.: 2 Specimenmark: 0393341 5/26/2010  Ra 0.306 Rz 2.870 Form removal : None Ls filter cut-off : 0.0 Lc filter cut-off : 800
File: R1_oil.dat Profile no.: 3 Specimenmark: 0393341 5/26/2010  Ra 0.313 Rz 2.248 Form removal : None Ls filter cut-off : 0.0 Lc filter cut-off : 800
File: R1_oil.dat Profile no.: 4 Specimenmark: 0393341 5/26/2010  Ra 0.332 Rz 2.300 Form removal : None Ls filter cut-off : 0.0 Lc filter cut-off : 800

Operator E – 23/03 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R2 – OIL (R0.3/M)

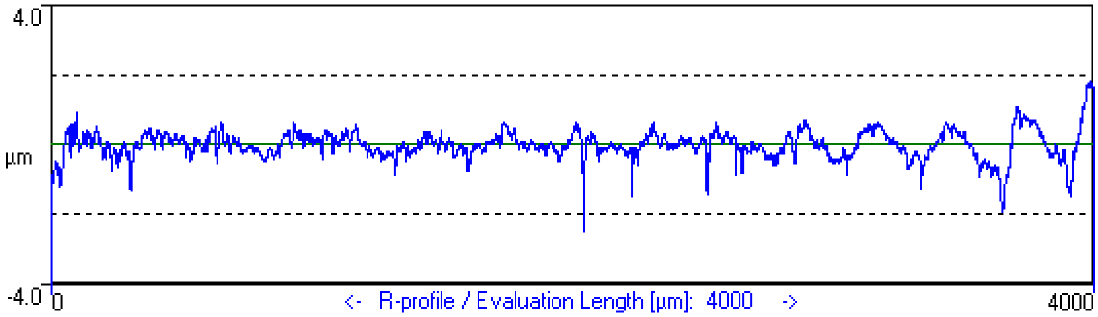
File: R2_oil.dat Profile no.: 1 Specimenmark: 0393341 5/26/2010



Ra 0.403
Rz 3.366

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

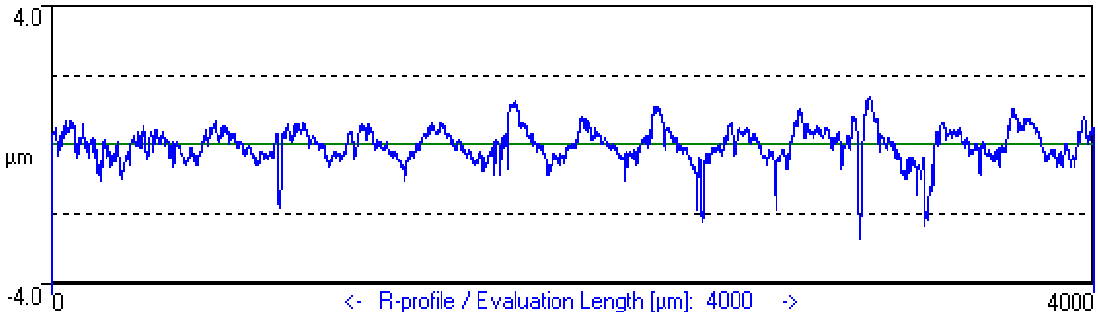
File: R2_oil.dat Profile no.: 2 Specimenmark: 0393341 5/26/2010



Ra 0.285
Rz 2.560

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

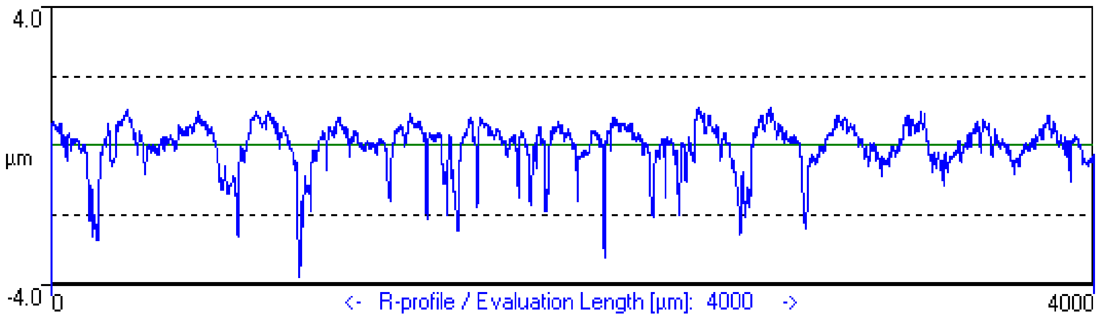
File: R2_oil.dat Profile no.: 3 Specimenmark: 0393341 5/26/2010



Ra 0.365
Rz 2.788

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: R2_oil.dat Profile no.: 4 Specimenmark: 0393341 5/26/2010



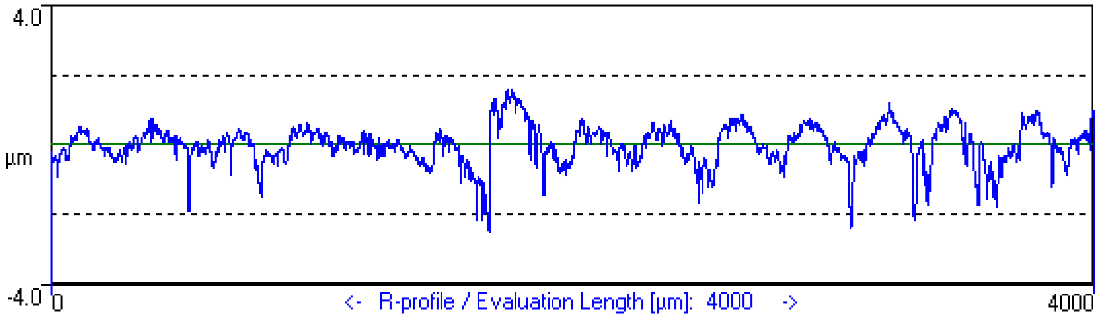
Ra 0.478
Rz 3.656

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

Operator E – 23/03 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R3 – OIL (R0.3/M)

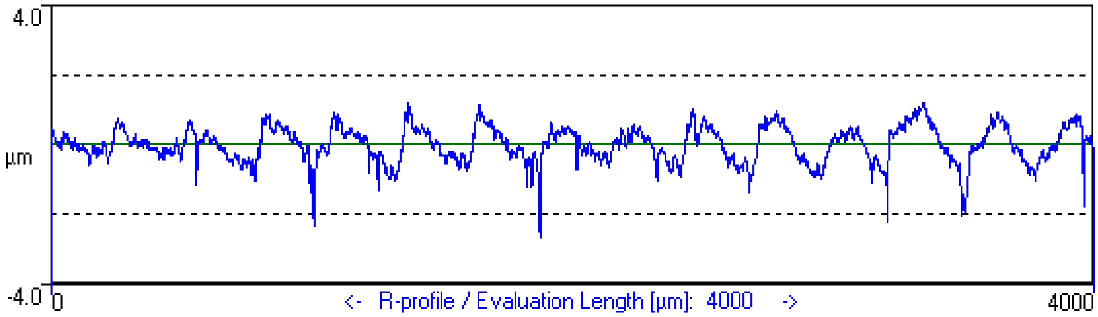
File: R3_oil.dat Profile no.: 1 Specimenmark: 0393341 5/26/2010



Ra 0.423
Rz 3.094

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

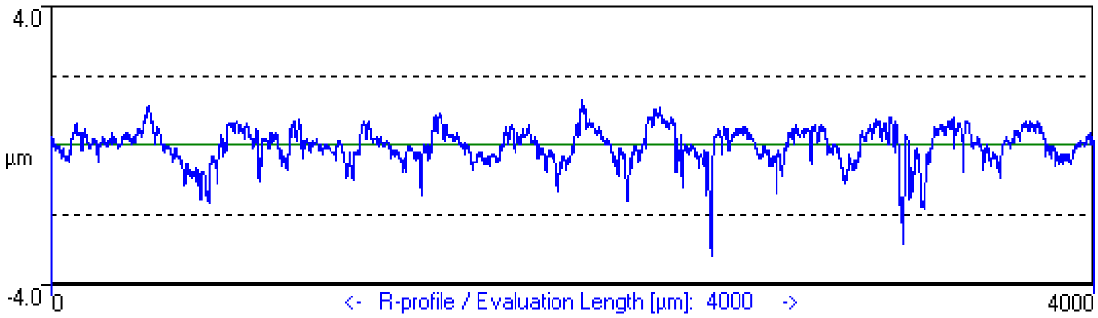
File: R3_oil.dat Profile no.: 2 Specimenmark: 0393341 5/26/2010



Ra 0.408
Rz 3.012

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

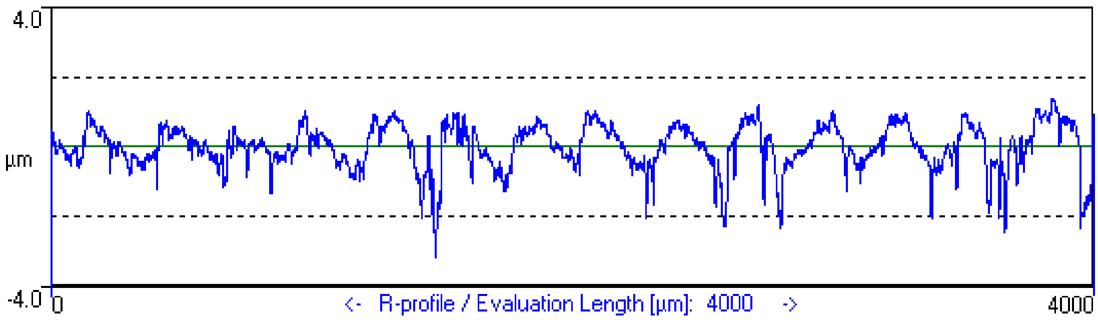
File: R3_oil.dat Profile no.: 3 Specimenmark: 0393341 5/26/2010



Ra 0.381
Rz 3.114

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: R3_oil.dat Profile no.: 4 Specimenmark: 0393341 5/26/2010



Ra 0.502
Rz 3.372

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

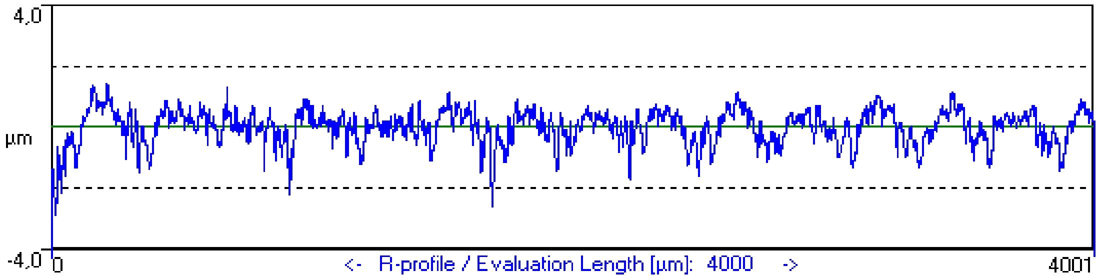
Appendix J2: Surface roughness measurement

Operator B: 12/04-2010

Operator B – 12/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P1 - 1% oil concentration (P0.3/W1)

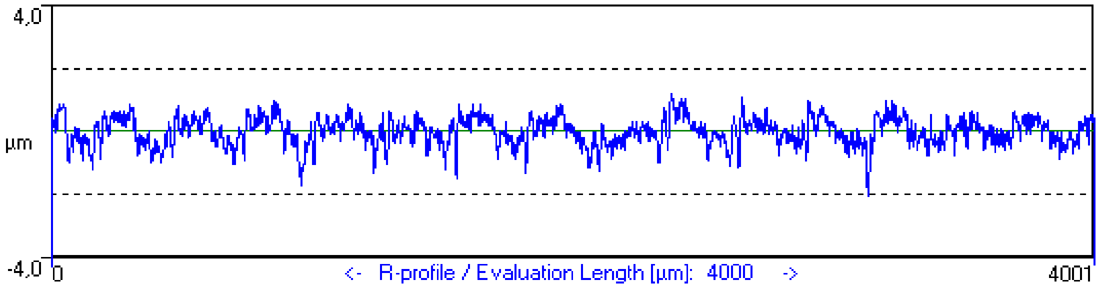
File: V1_1%.dat Profile no.: 1 Specimenmark: 0393341 16-06-2010



Ra 0,446
Rz 3,278
Rzmax 4,280

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

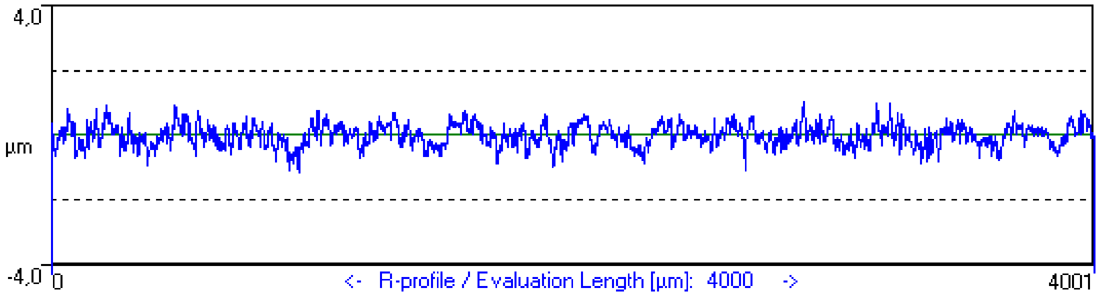
File: V1_1%.dat Profile no.: 2 Specimenmark: 0393341 16-06-2010



Ra 0,350
Rz 2,446
Rzmax 3,130

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

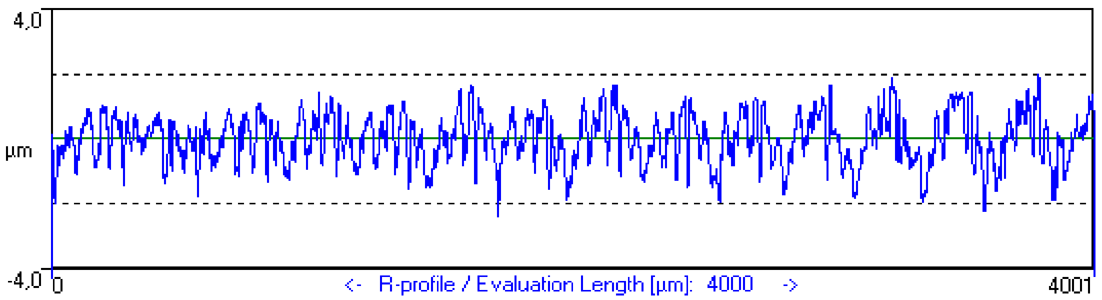
File: V1_1%.dat Profile no.: 3 Specimenmark: 0393341 16-06-2010



Ra 0,267
Rz 1,870
Rzmax 2,100

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: V1_1%.dat Profile no.: 4 Specimenmark: 0393341 16-06-2010



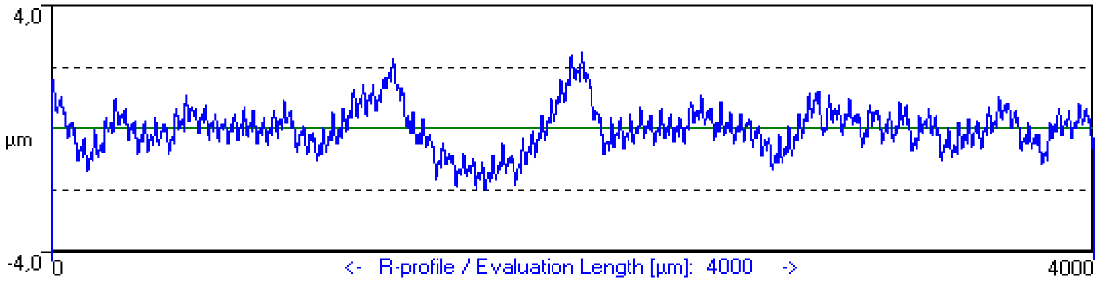
Ra 0,621
Rz 3,588
Rzmax 4,180

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator B – 12/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P2 – 1% oil concentration (P0.3/W1)

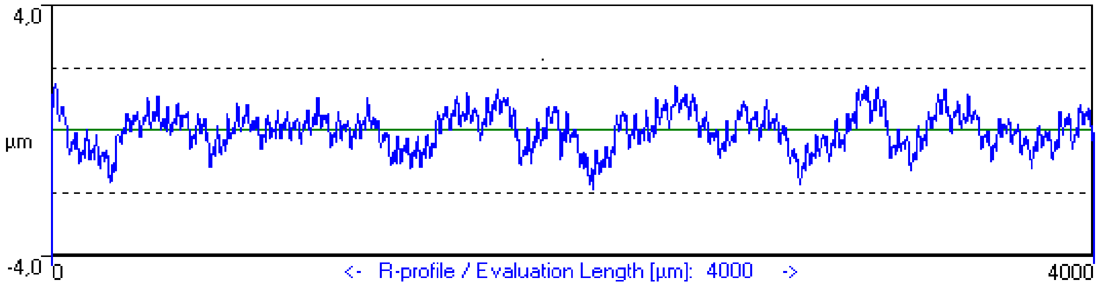
File: V2_1%.dat   Profile no.: 1   Specimenmark: 0393341   16-06-2010



Ra 0,531
Rz 3,268
Rzmax 4,480

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

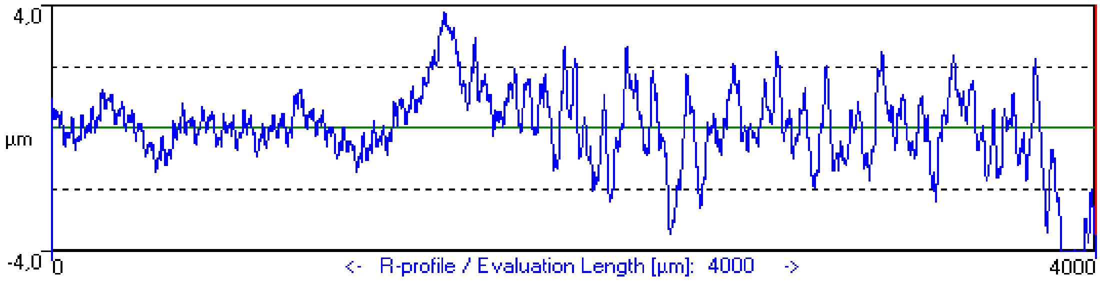
File: V2_1%.dat   Profile no.: 2   Specimenmark: 0393341   16-06-2010



Ra 0,481
Rz 2,904
Rzmax 3,250

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

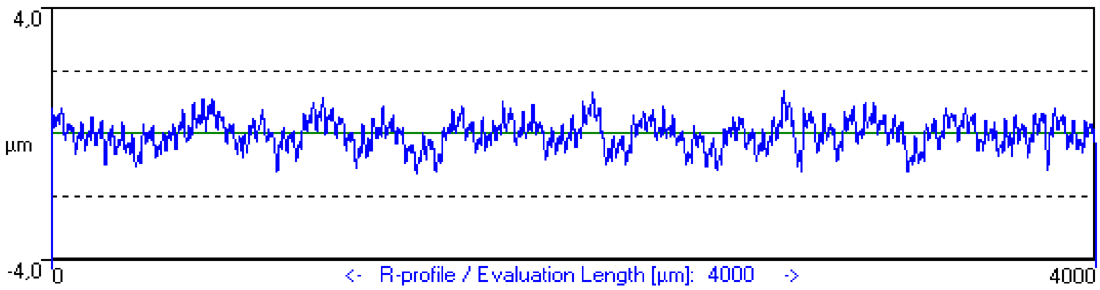
File: V2_1%   Profile no.: 3   Specimenmark: 0393341   15-06-2010



Ra 0,933
Rz 5,408
Rzmax 7,640

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: V2_1%   Profile no.: 4   Specimenmark: 0393341   15-06-2010



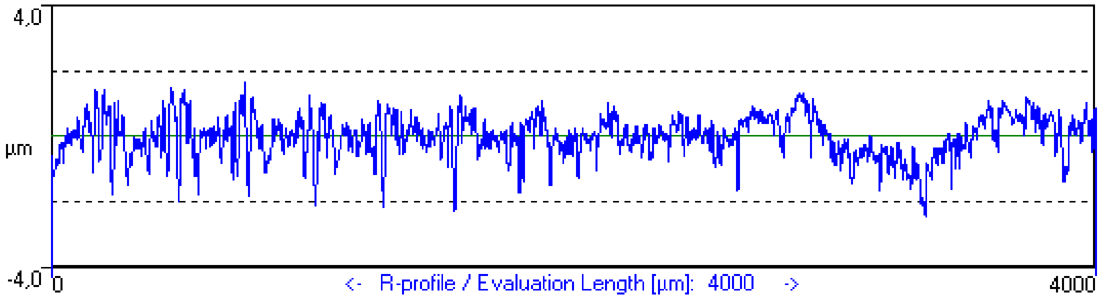
Ra 0,369
Rz 2,306
Rzmax 2,550

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator B – 12/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P3 - 1% oil concentration (P0.3/W1)

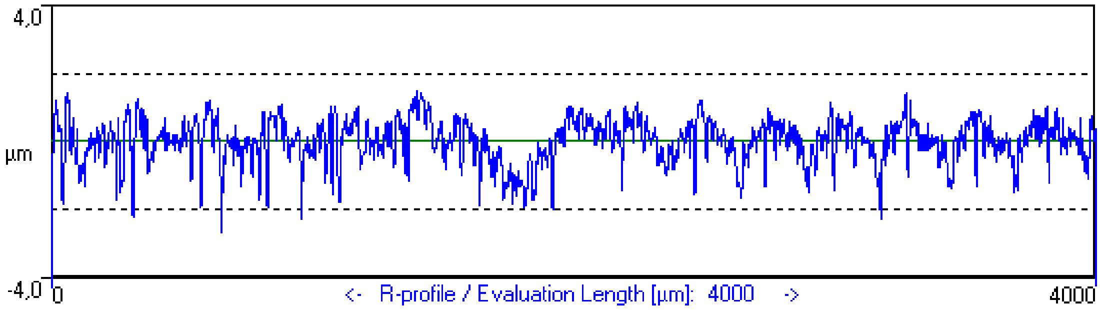
File: V3_1% Profile no.: 1 Specimenmark: 0393341 15-06-2010



Ra 0,488
Rz 3,310
Rzmax 3,610

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

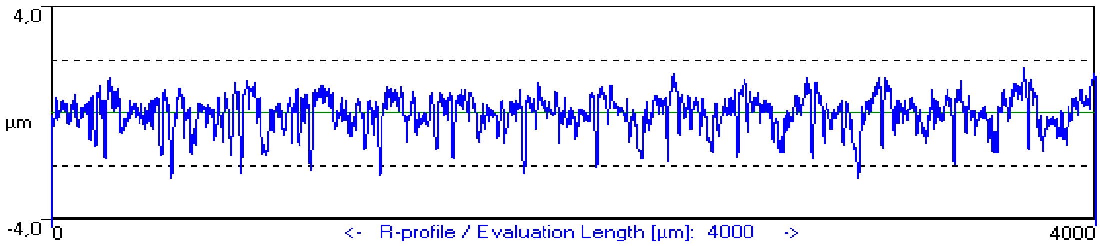
File: V3_1% Profile no.: 2 Specimenmark: 0393341 15-06-2010



Ra 0,497
Rz 3,452
Rzmax 4,030

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

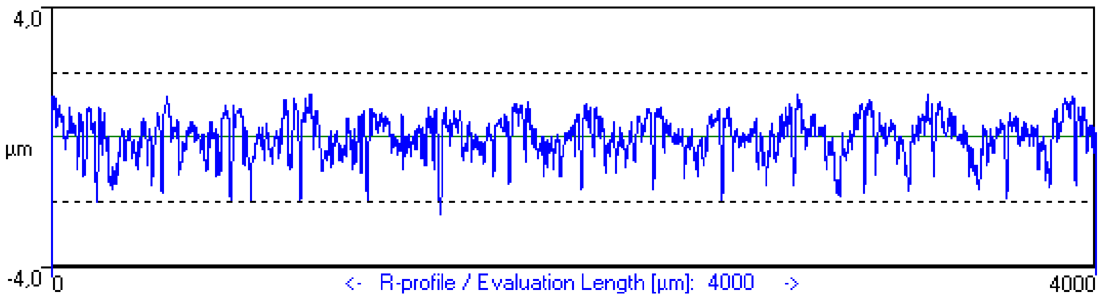
File: V3_1% Profile no.: 3 Specimenmark: 0393341 15-06-2010



Ra 0,509
Rz 3,652
Rzmax 3,790

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: V3_1% Profile no.: 4 Specimenmark: 0393341 15-06-2010



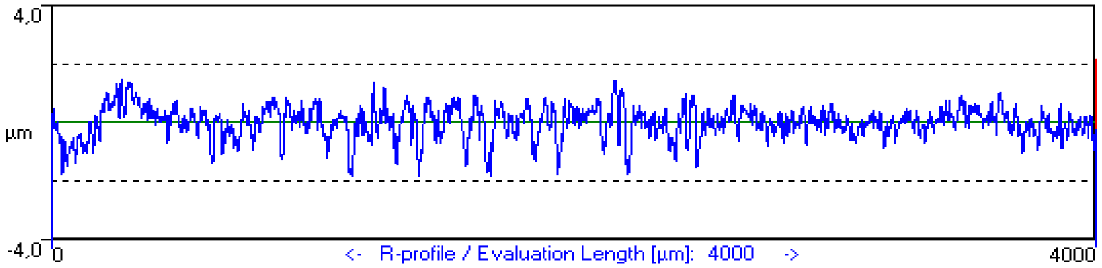
Ra 0,493
Rz 3,218
Rzmax 3,710

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator B – 12/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R1 - 1% oil concentration (R0.3/W1)

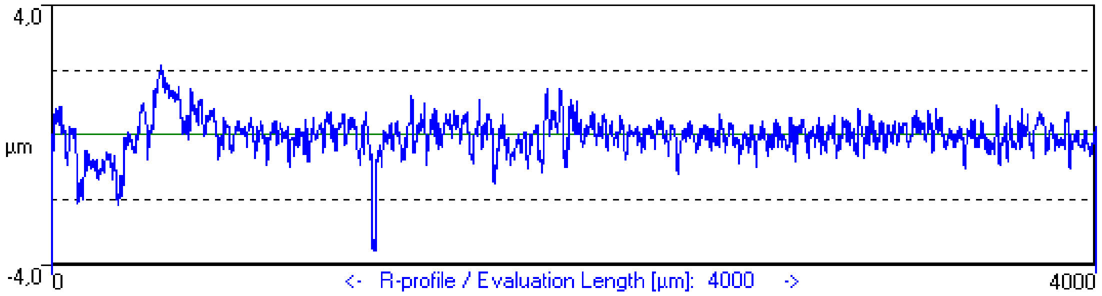
File: VP1_1%   Profile no.: 1   Specimenmark: 0393341   15-06-2010



Ra 0,405
Rz 2,864
Rzmax 3,260

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

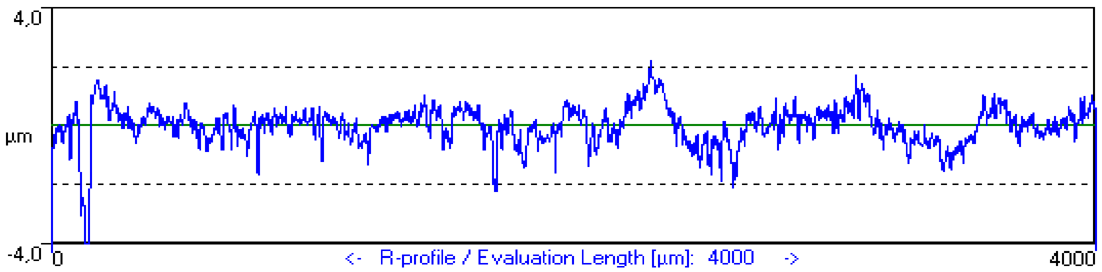
File: VP1_1%   Profile no.: 2   Specimenmark: 0393341   15-06-2010



Ra 0,392
Rz 3,140
Rzmax 4,740

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

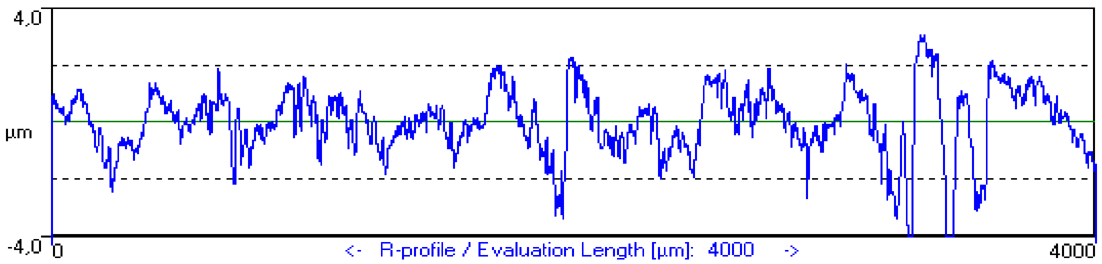
File: VP1_1%   Profile no.: 3   Specimenmark: 0393341   15-06-2010



Ra 0,478
Rz 4,156
Rzmax 7,550

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: VP1_1%   Profile no.: 4   Specimenmark: 0393341   15-06-2010



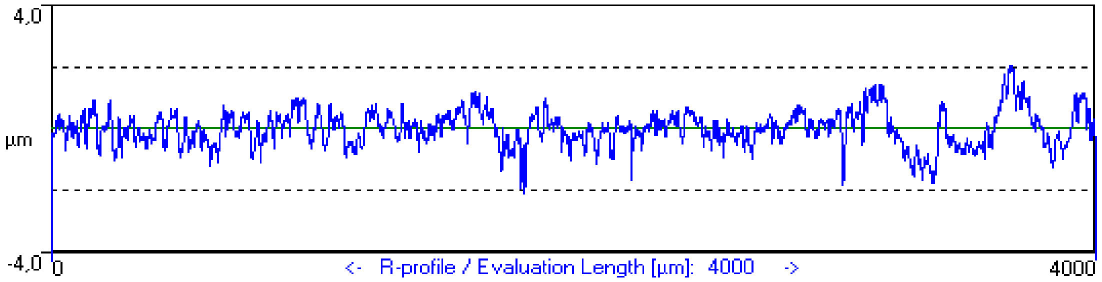
Ra 0,894
Rz 5,300
Rzmax 8,400
RSm 79,223

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator B – 12/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R2 - 1% oil concentration (R0.3/W1)

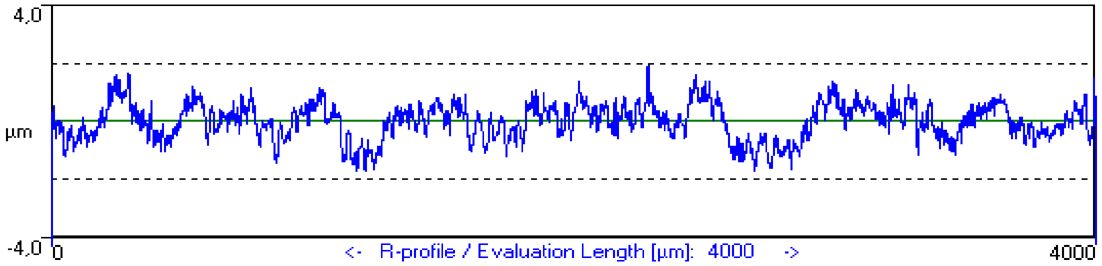
File: VP2_1% Profile no.: 1 Specimenmark: 0393341 15-06-2010



Ra 0,440
Rz 2,900
Rzmax 3,840

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

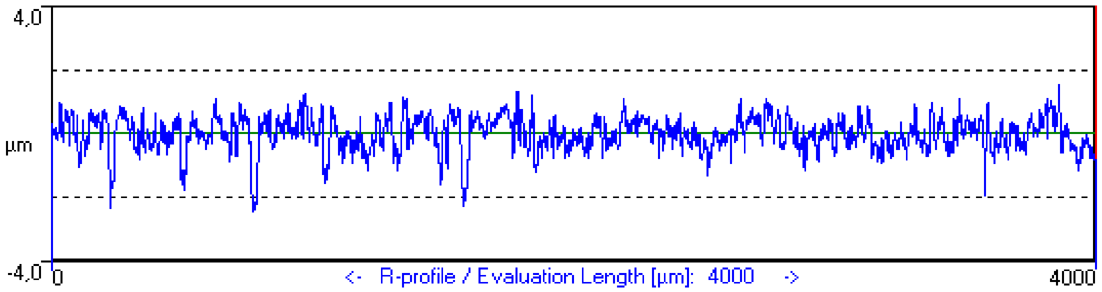
File: VP2_1% Profile no.: 2 Specimenmark: 0393341 15-06-2010



Ra 0,503
Rz 2,950
Rzmax 3,280

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

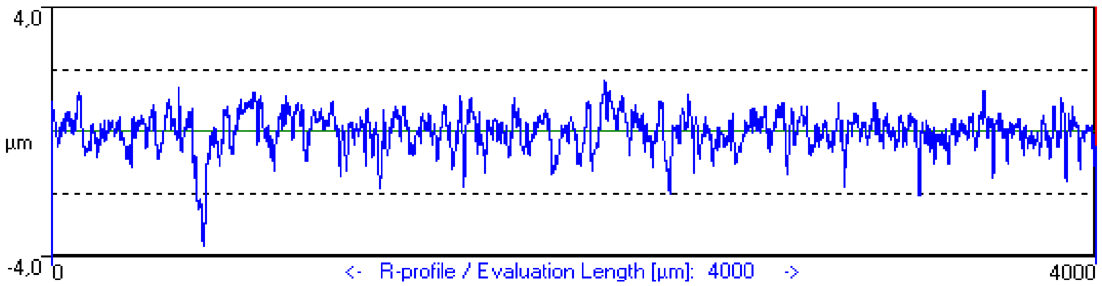
File: VP2_1% Profile no.: 3 Specimenmark: 0393341 15-06-2010



Ra 0,414
Rz 3,088
Rzmax 3,510

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: VP2_1% Profile no.: 4 Specimenmark: 0393341 15-06-2010



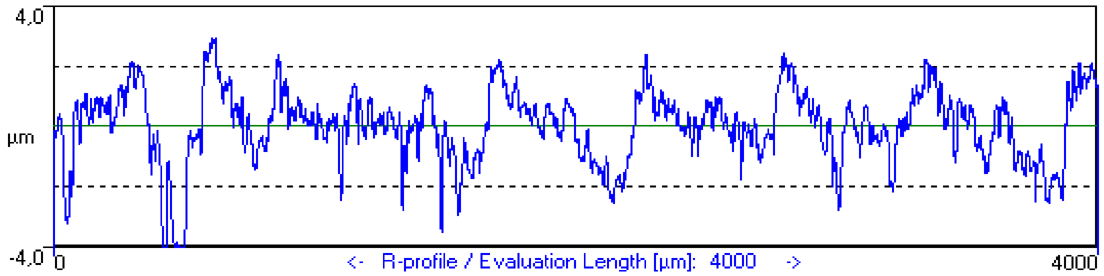
Ra 0,438
Rz 3,616
Rzmax 5,080

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator B – 12/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R3 - 1% oil concentration (R0.3/W1)

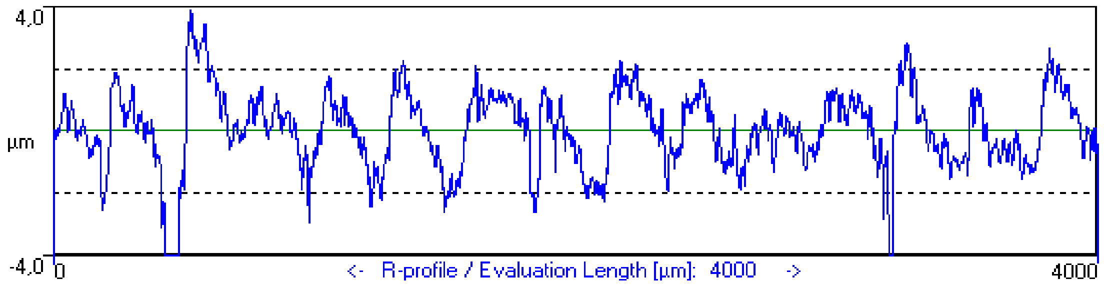
File: VP3_1% Profile no.: 1 Specimenmark: 0393341 15-06-2010



Ra 0,938
Rz 5,964
Rzmax 9,070

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

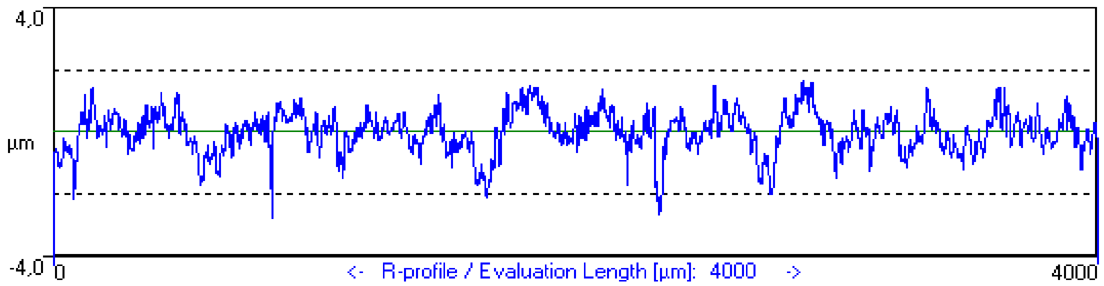
File: VP3_1% Profile no.: 2 Specimenmark: 0393341 15-06-2010



Ra 1,001
Rz 7,476
Rzmax 12,610

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

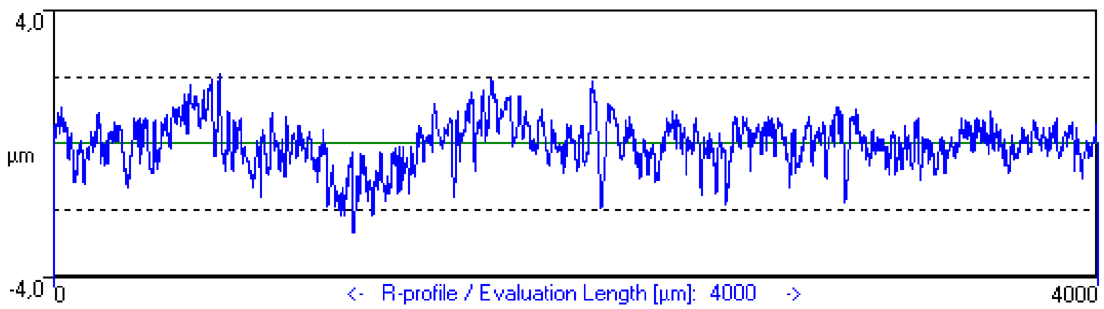
File: VP3_1% Profile no.: 3 Specimenmark: 0393341 15-06-2010



Ra 0,497
Rz 3,602
Rzmax 4,150

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: VP3_1% Profile no.: 4 Specimenmark: 0393341 15-06-2010

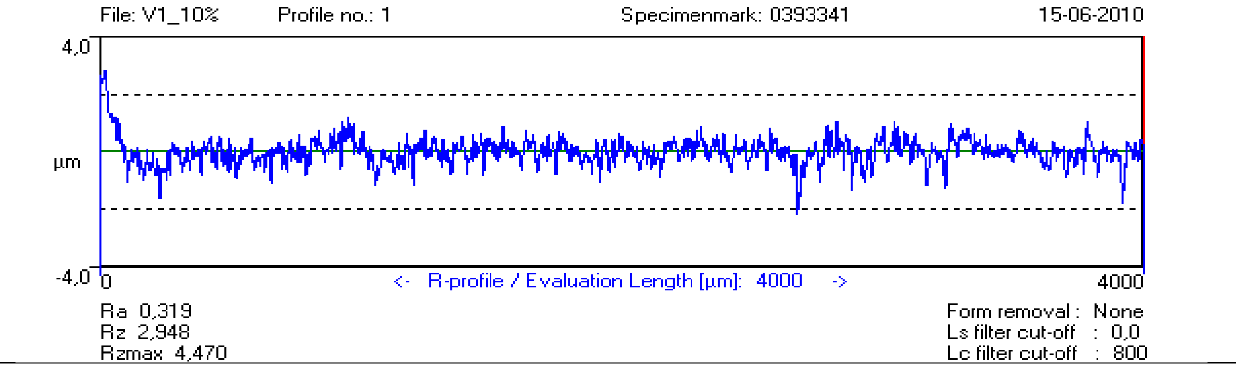


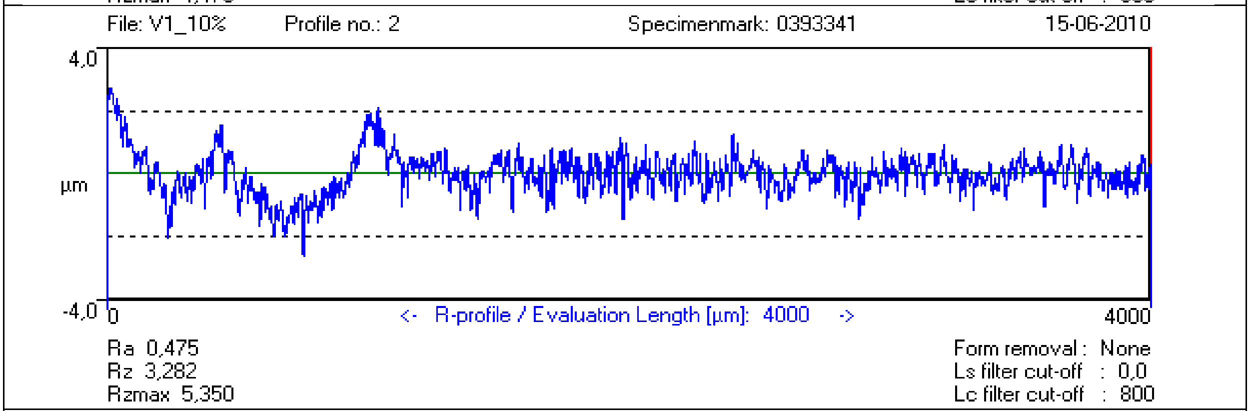
Ra 0,522
Rz 3,348
Rzmax 4,200

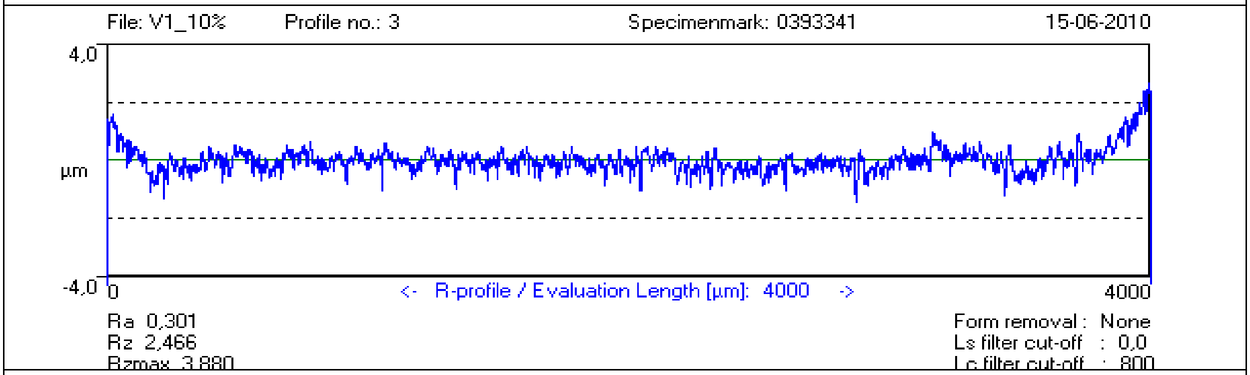
Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

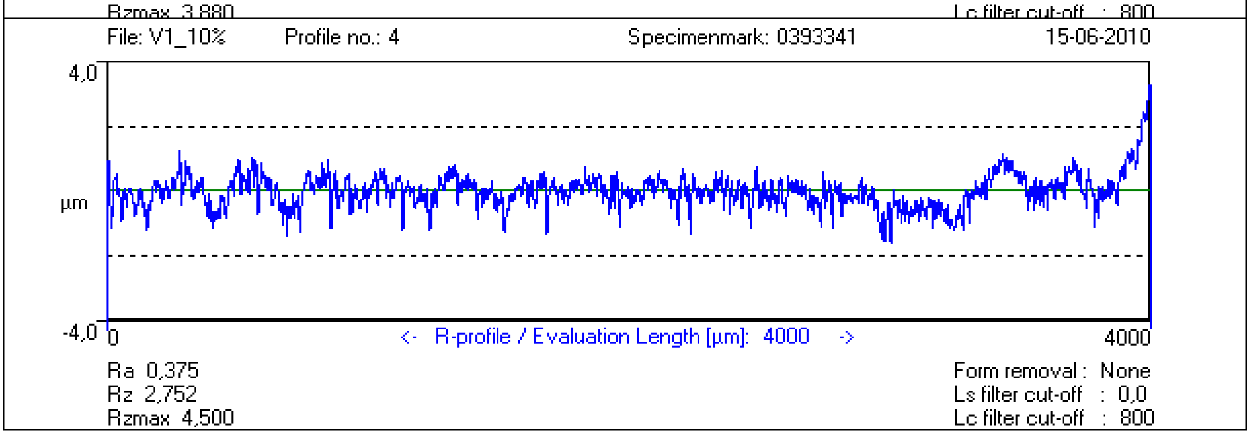
Operator B – 12/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P1 - 10% oil concentration (P0.3/W2)





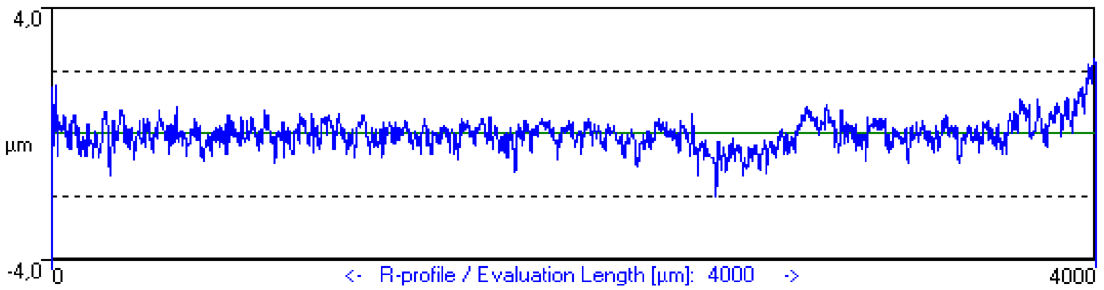




Operator B – 12/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P2 - 10% oil concentration (P0.3/W2)

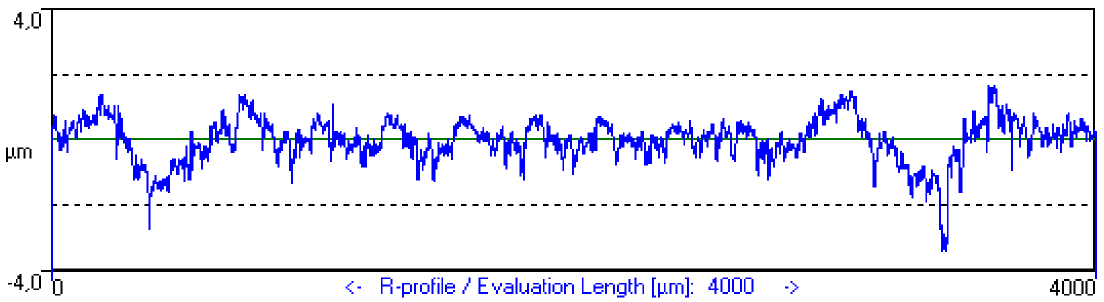
File: V2_10% Profile no.: 1 Specimenmark: 0393341 15-06-2010



Ra 0,331
Rz 2,516
Rzmax 3,330

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

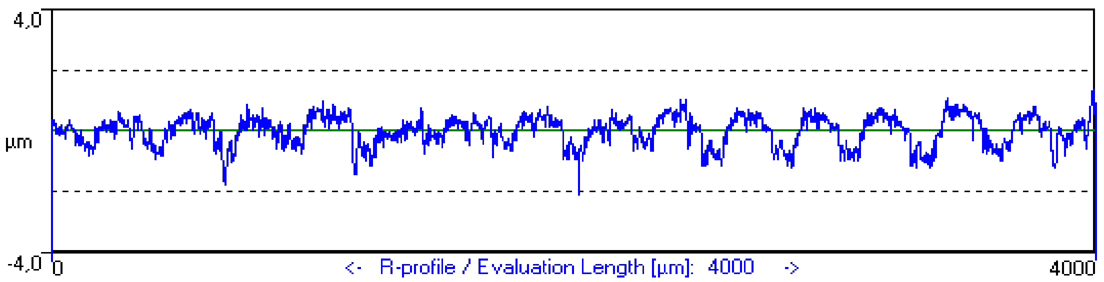
File: V2_10% Profile no.: 2 Specimenmark: 0393341 15-06-2010



Ra 0,487
Rz 3,290
Rzmax 5,040

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

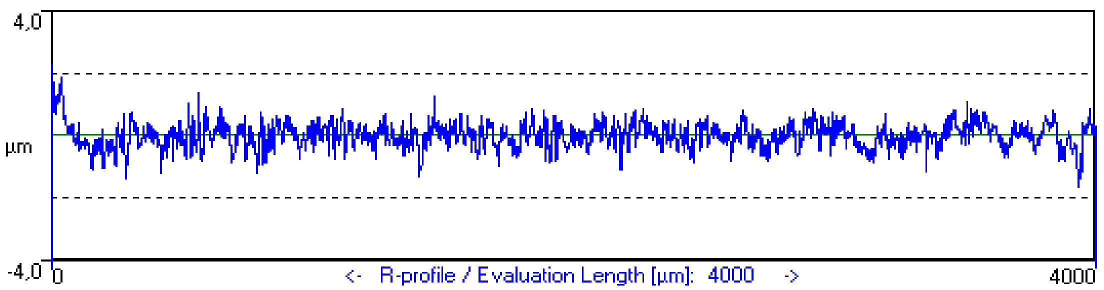
File: V2_10% Profile no.: 3 Specimenmark: 0393341 15-06-2010



Ra 0,397
Rz 2,552
Rzmax 2,910

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: V2_10% Profile no.: 4 Specimenmark: 0393341 15-06-2010



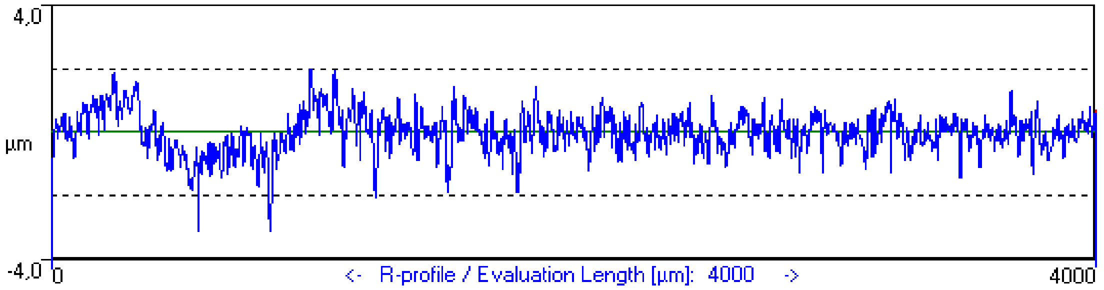
Ra 0,312
Rz 2,522
Rzmax 3,630

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator B – 12/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P3 - 10% oil concentration (P0.3/W2)

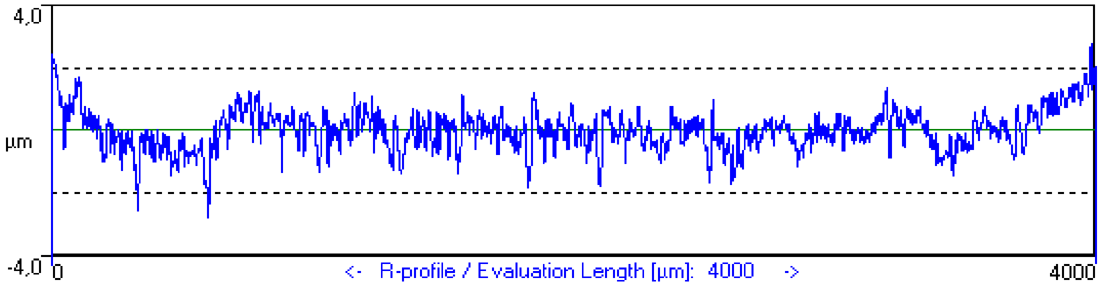
File: V3_10% Profile no.: 1 Specimenmark: 0393341 15-06-2010



Ra 0,465
Rz 3,684
Rzmax 5,080

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

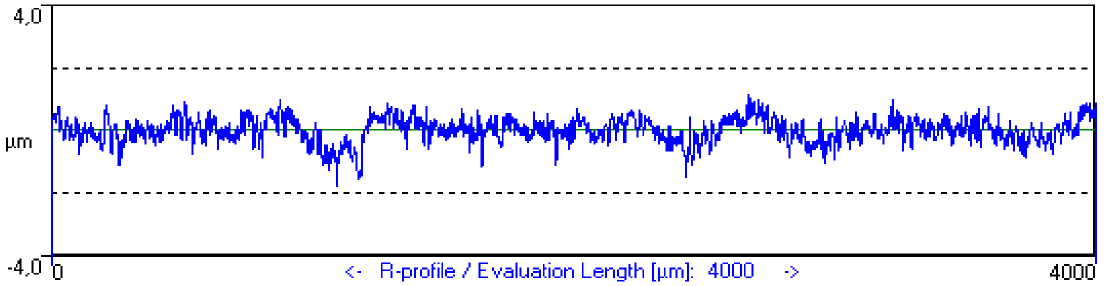
File: V3_10% Profile no.: 2 Specimenmark: 0393341 15-06-2010



Ra 0,489
Rz 3,624
Rzmax 5,220

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

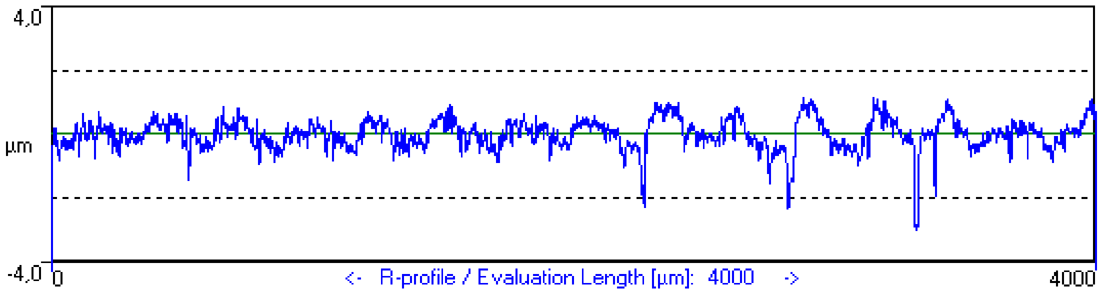
File: V3_10% Profile no.: 3 Specimenmark: 0393341 15-06-2010



Ra 0,304
Rz 2,208
Rzmax 2,730

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: V3_10% Profile no.: 4 Specimenmark: 0393341 15-06-2010



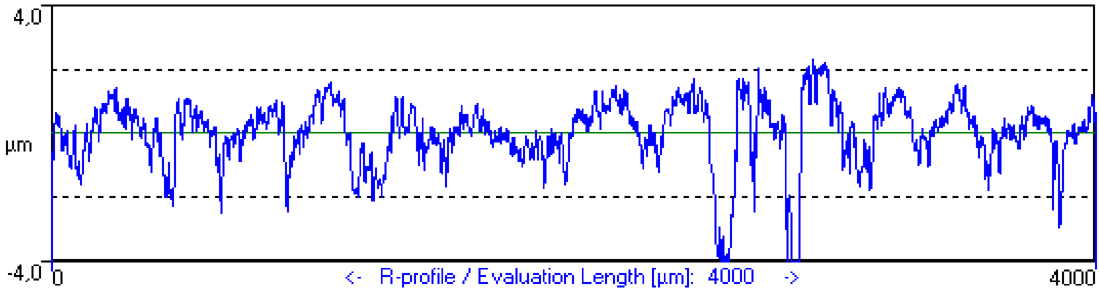
Ra 0,353
Rz 2,968
Rzmax 4,080

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator B – 12/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R1 - 10% oil concentration (R0.3/W2)

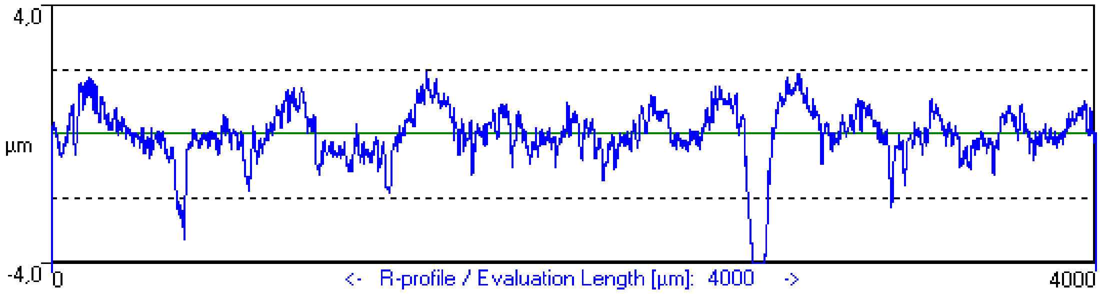
File: VP1_10% Profile no.: 1 Specimenmark: 0393341 15-06-2010



Ra 0,769
Rz 4,998
Rzmax 9,370

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

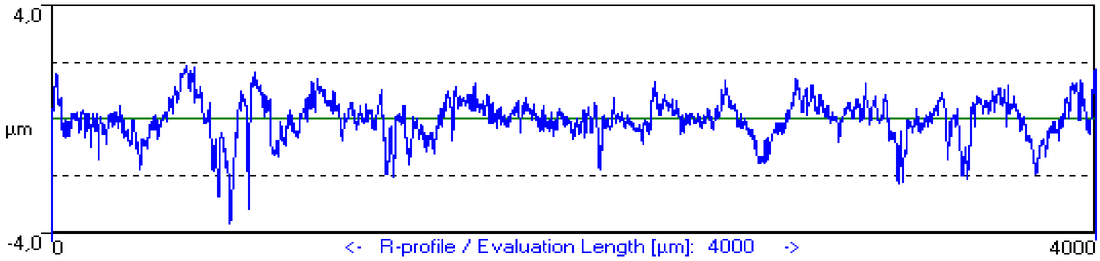
File: VP1_10% Profile no.: 2 Specimenmark: 0393341 15-06-2010



Ra 0,590
Rz 4,288
Rzmax 6,730

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

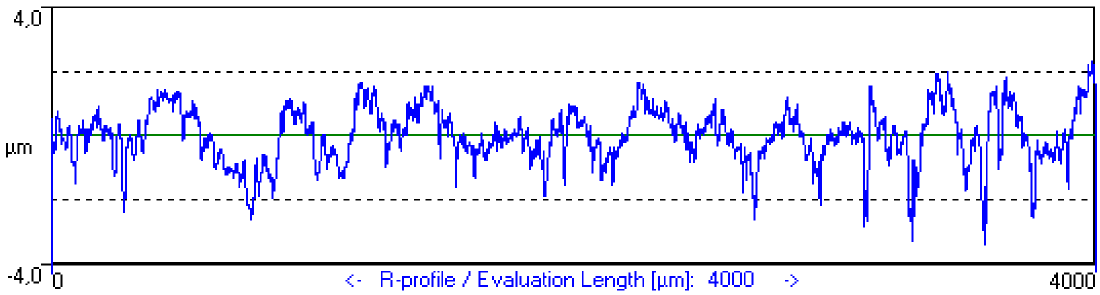
File: VP1_10% Profile no.: 3 Specimenmark: 0393341 15-06-2010



Ra 0,527
Rz 3,818
Rzmax 5,510

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: VP1_10% Profile no.: 4 Specimenmark: 0393341 15-06-2010



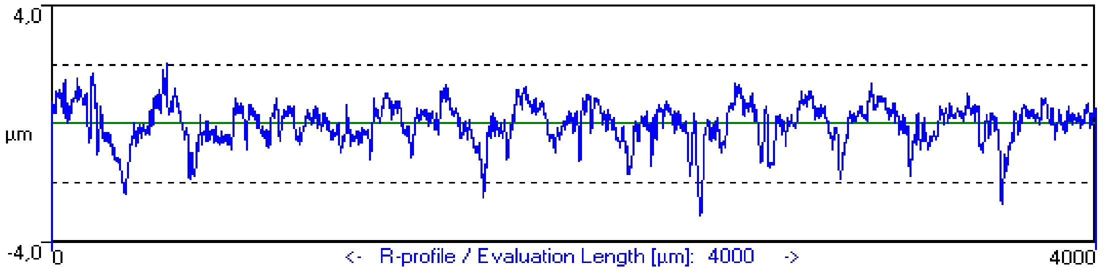
Ra 0,670
Rz 4,246
Rzmax 5,680

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator B – 12/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R2 - 10% oil concentration (R0.3/W2)

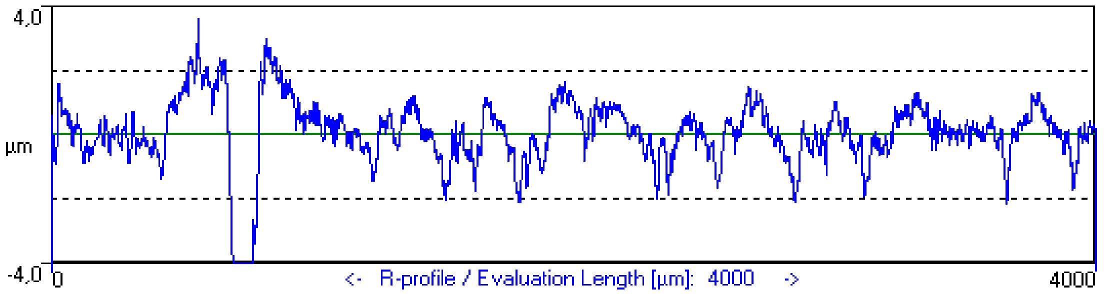
File: VP2_10% Profile no.: 1 Specimenmark: 0393341 15-06-2010



Ra 0,519
Rz 3,786
Rzmax 4,490

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

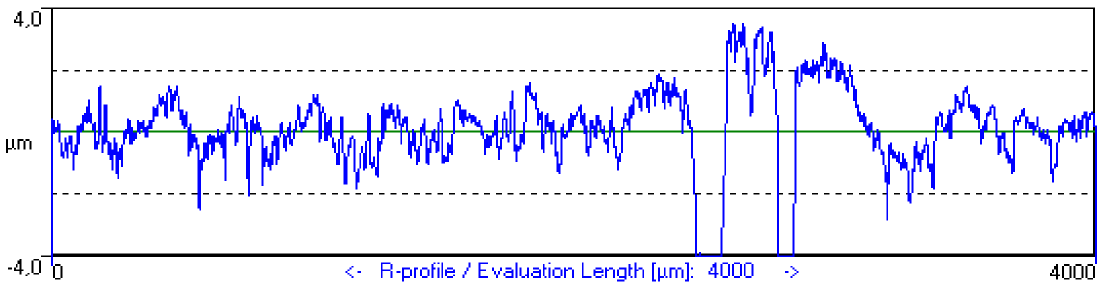
File: VP2_10% Profile no.: 2 Specimenmark: 0393341 15-06-2010



Ra 0,781
Rz 6,540
Rzmax 16,840

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

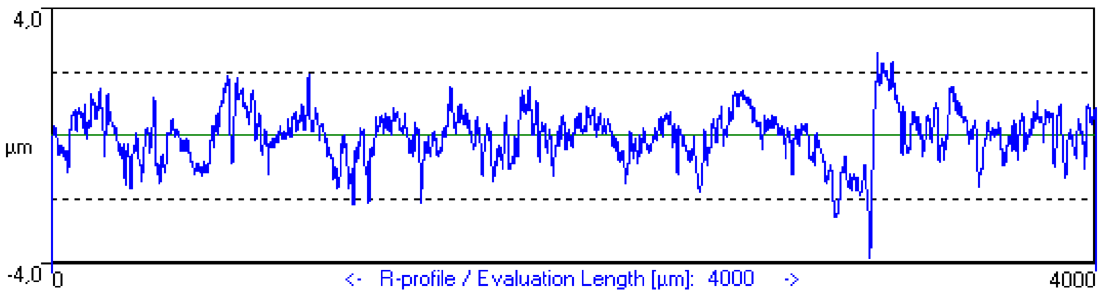
File: VP2_10% Profile no.: 3 Specimenmark: 0393341 15-06-2010



Ra 0,994
Rz 5,996
Rzmax 15,460

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: VP2_10% Profile no.: 4 Specimenmark: 0393341 15-06-2010



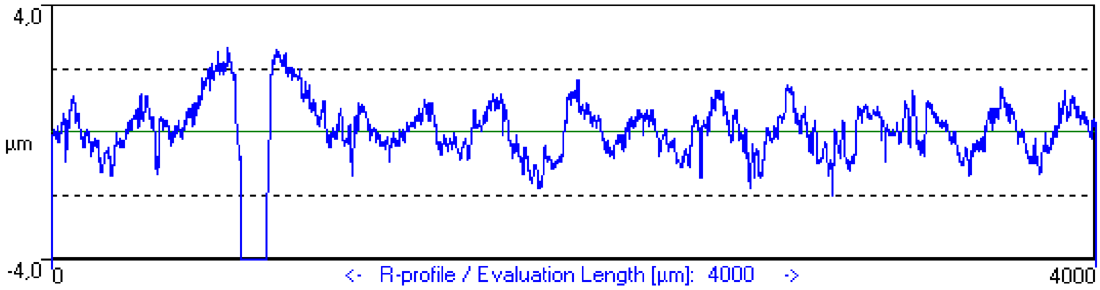
Ra 0,604
Rz 4,190
Rzmax 6,440

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator B – 12/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R3 - 10% oil concentration (R0.3/W2)

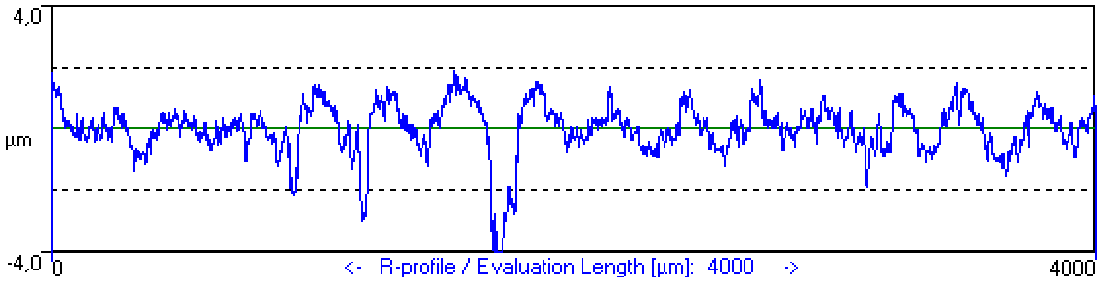
File: VP3_10% Profile no.: 1 Specimenmark: 0393341 15-06-2010



Ra 0,761
Rz 6,030
Rzmax 11,270

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

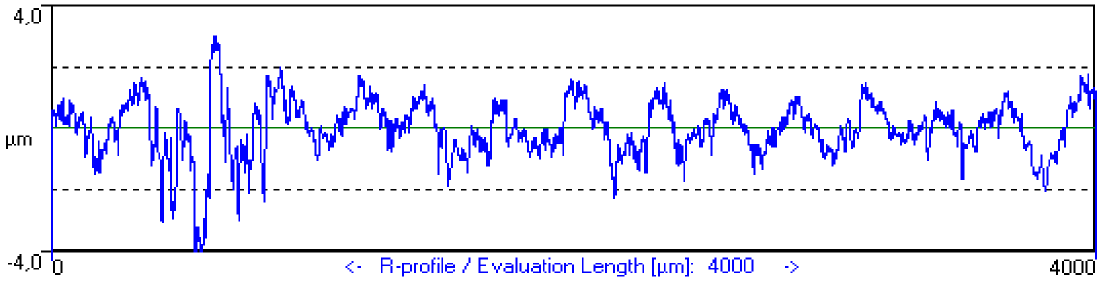
File: VP3_10% Profile no.: 2 Specimenmark: 0393341 15-06-2010



Ra 0,601
Rz 4,242
Rzmax 6,720

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

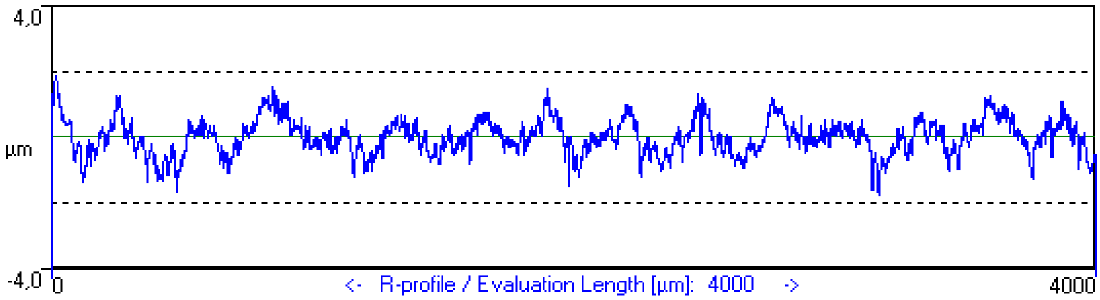
File: VP3_10% Profile no.: 3 Specimenmark: 0393341 15-06-2010



Ra 0,698
Rz 4,642
Rzmax 7,930

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: VP3_10% Profile no.: 4 Specimenmark: 0393341 15-06-2010



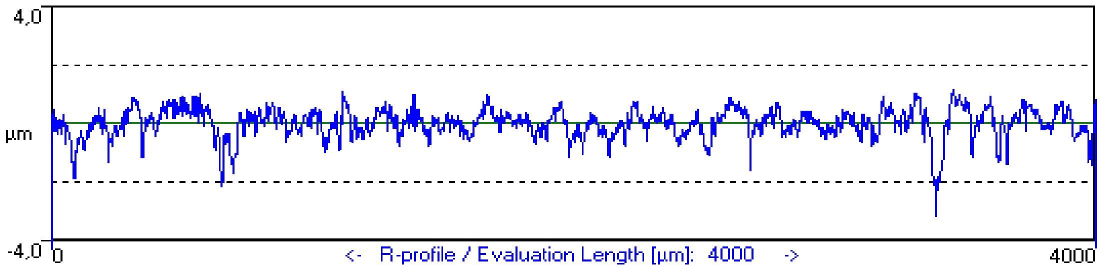
Ra 0,431
Rz 2,986
Rzmax 3,540

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator B – 12/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P1 – OIL (P0.3/M)

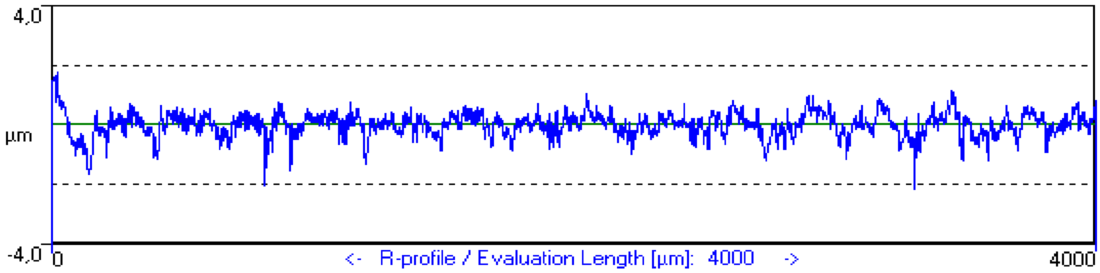
File: V1_oil Profile no.: 1 Specimenmark: 0393341 15-06-2010



Ra 0,371
Rz 2,830
Rzmax 4,300

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

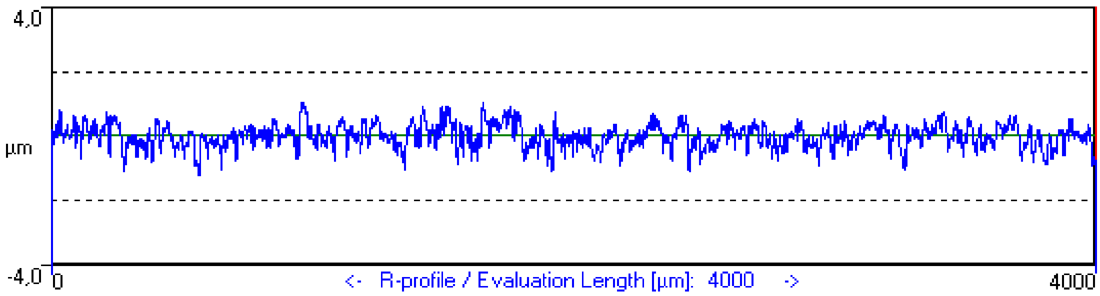
File: V1_oil Profile no.: 2 Specimenmark: 0393341 15-06-2010



Ra 0,305
Rz 2,754
Rzmax 3,440

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

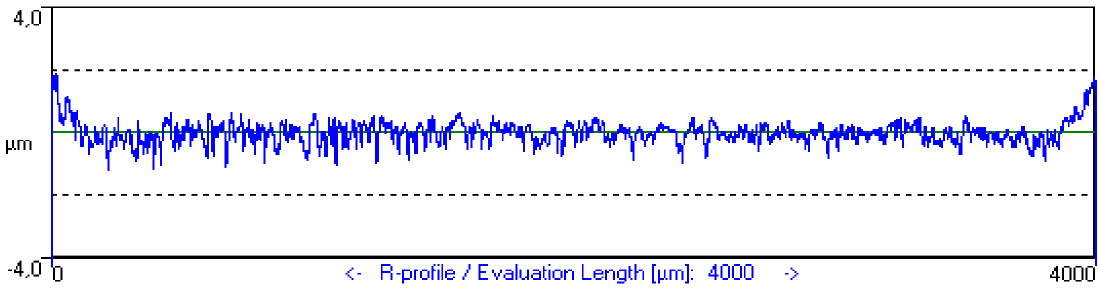
File: V1_oil Profile no.: 3 Specimenmark: 0393341 15-06-2010



Ra 0,284
Rz 1,980
Rzmax 2,170

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: V1_oil Profile no.: 4 Specimenmark: 0393341 15-06-2010



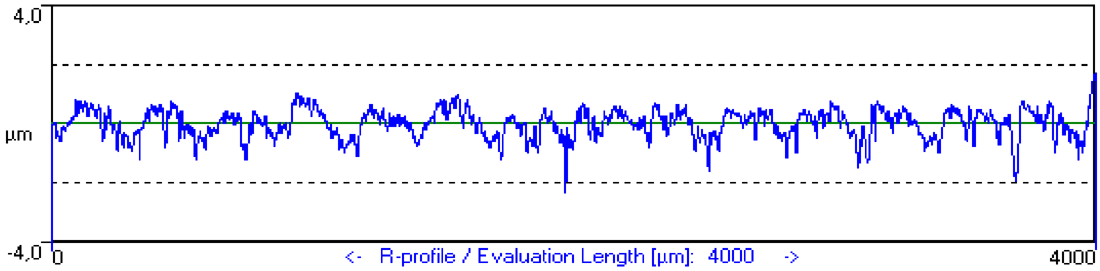
Ra 0,264
Rz 2,072
Rzmax 3,120

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator B – 12/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P2 –OIL (P0.3/M)

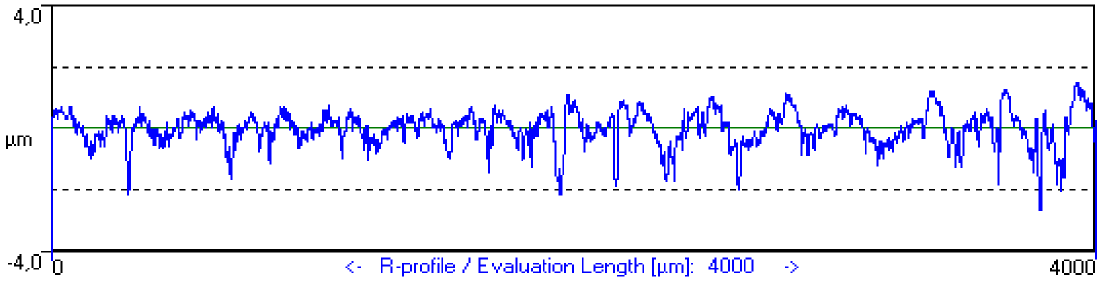
File: V2_oil   Profile no.: 1   Specimenmark: 0393341   15-06-2010



Ra 0,383
Rz 2,630
Rzmax 3,610

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

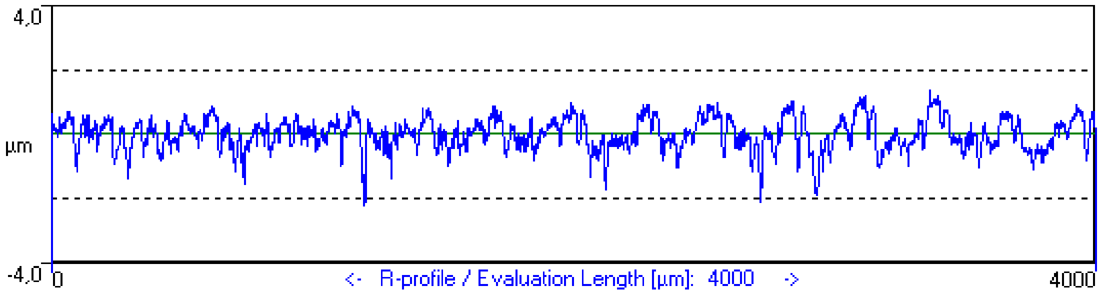
File: V2_oil   Profile no.: 2   Specimenmark: 0393341   15-06-2010



Ra 0,423
Rz 3,068
Rzmax 4,190

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

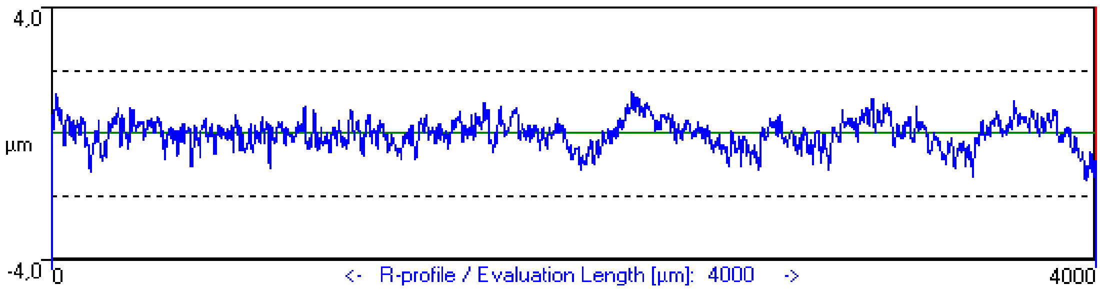
File: V2_oil   Profile no.: 3   Specimenmark: 0393341   15-06-2010



Ra 0,391
Rz 2,766
Rzmax 3,250

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: V2_oil   Profile no.: 4   Specimenmark: 0393341   15-06-2010



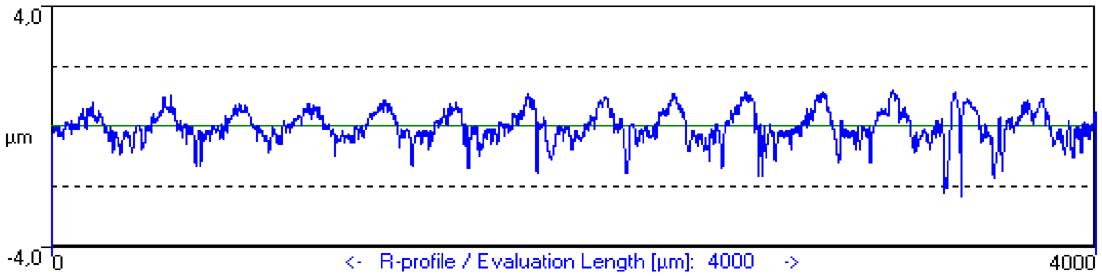
Ra 0,345
Rz 2,302
Rzmax 2,490

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator B – 12/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P3 – OIL (P0.3/M)

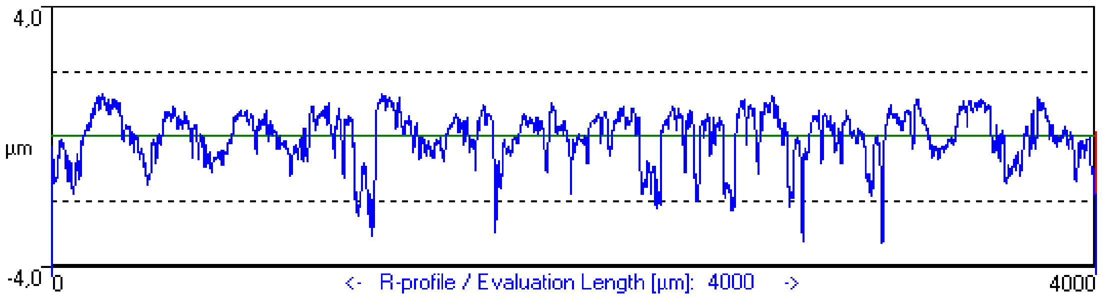
File: V3_oil Profile no.: 1 Specimenmark: 0393341 15-06-2010



Ra 0,406
Rz 2,722
Rzmax 3,520

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

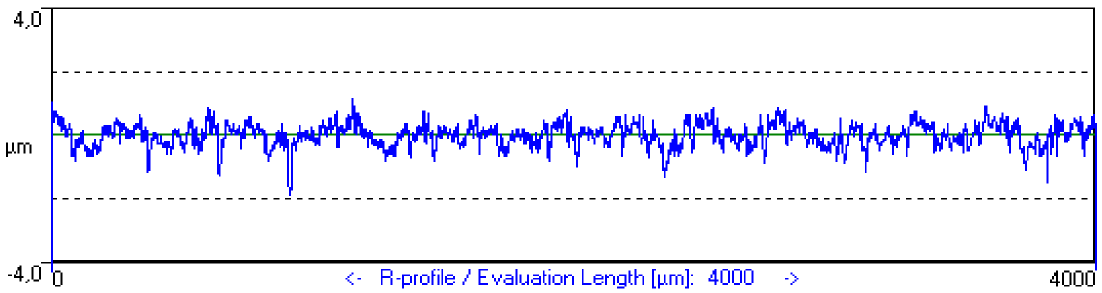
File: V3_oil Profile no.: 2 Specimenmark: 0393341 15-06-2010



Ra 0,609
Rz 3,786
Rzmax 4,510

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

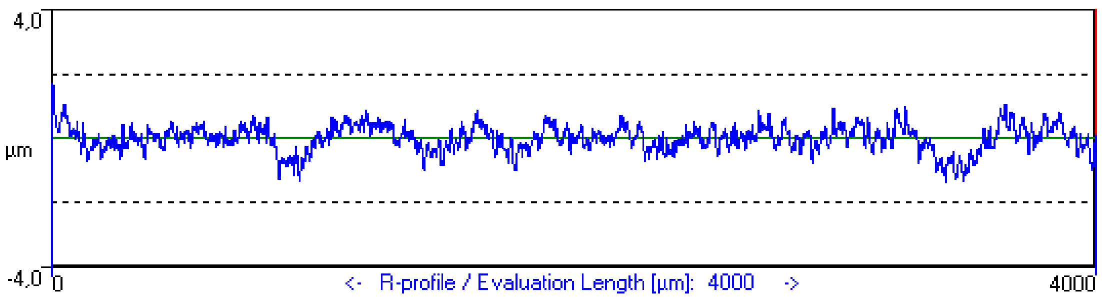
File: V3_oil Profile no.: 3 Specimenmark: 0393341 15-06-2010



Ra 0,285
Rz 2,380
Rzmax 3,050

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: V3_oil Profile no.: 4 Specimenmark: 0393341 15-06-2010



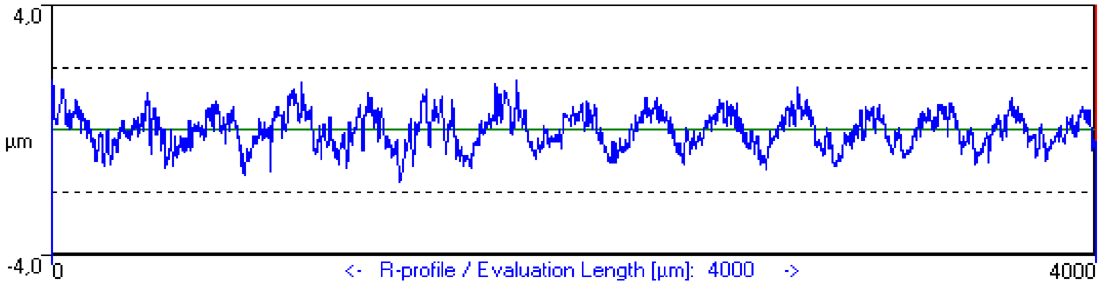
Ra 0,312
Rz 2,104
Rzmax 2,450

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator B – 12/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R1 – OIL (R0.3/M)

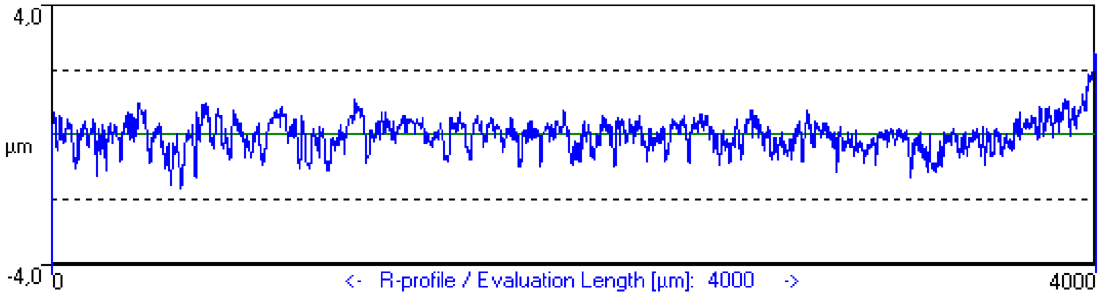
File: VP1_oil Profile no.: 1 Specimenmark: 0393341 15-06-2010



Ra 0,455
Rz 2,758
Rzmax 3,190

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

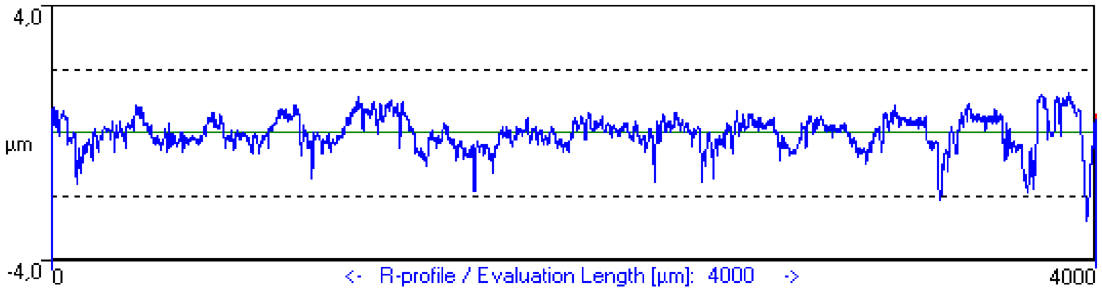
File: VP1_oil Profile no.: 2 Specimenmark: 0393341 15-06-2010



Ra 0,363
Rz 2,462
Rzmax 3,870

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

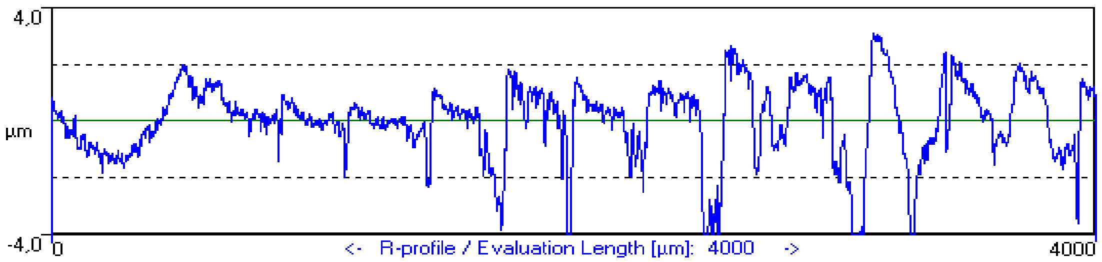
File: VP1_oil Profile no.: 3 Specimenmark: 0393341 15-06-2010



Ra 0,391
Rz 2,760
Rzmax 4,050

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: VP1_oil Profile no.: 4 Specimenmark: 0393341 15-06-2010



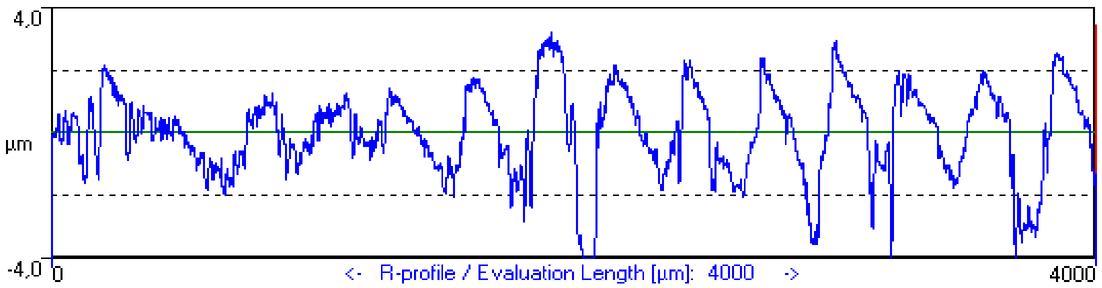
Ra 1,025
Rz 6,496
Rzmax 11,470

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator B – 12/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R2 – OIL (R0.3/M)

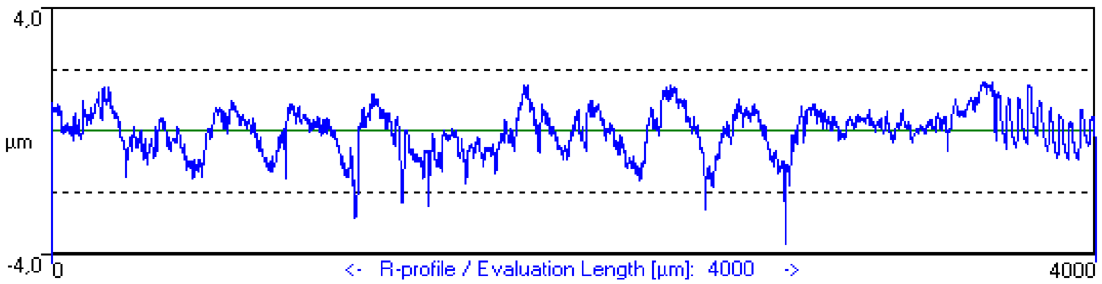
File: VP2_oil Profile no.: 1 Specimenmark: 0393341 15-06-2010



Ra 1,124
Rz 6,200
Rzmax 10,010

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

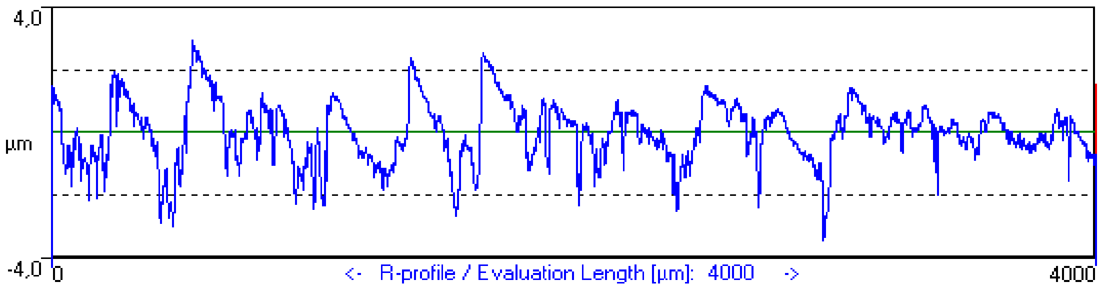
File: VP2_oil Profile no.: 2 Specimenmark: 0393341 15-06-2010



Ra 0,562
Rz 3,456
Rzmax 4,680

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

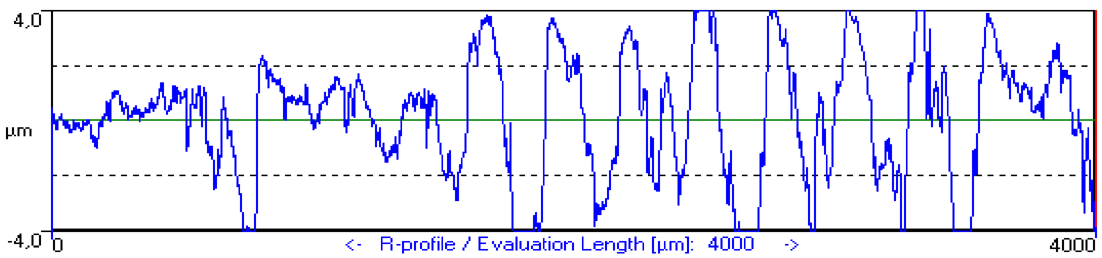
File: VP2_oil Profile no.: 3 Specimenmark: 0393341 15-06-2010



Ra 0,755
Rz 4,744
Rzmax 5,900

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: VP2_oil Profile no.: 4 Specimenmark: 0393341 15-06-2010



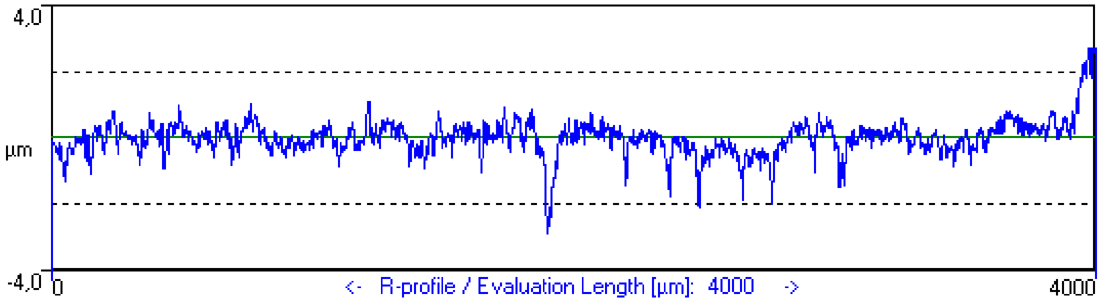
Ra 1,889
Rz 10,328
Rzmax 14,110

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator B – 12/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R3 – OIL (R0.3/M)

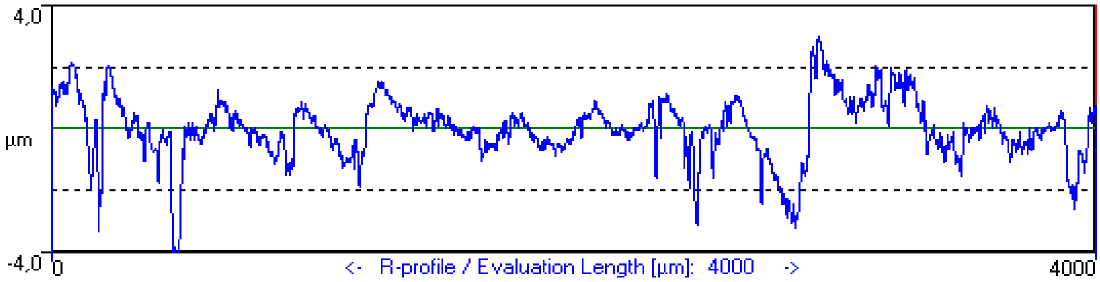
File: VP3_oil Profile no.: 1 Specimenmark: 0393341 15-06-2010



Ra 0,357
Rz 2,910
Rzmax 3,800

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

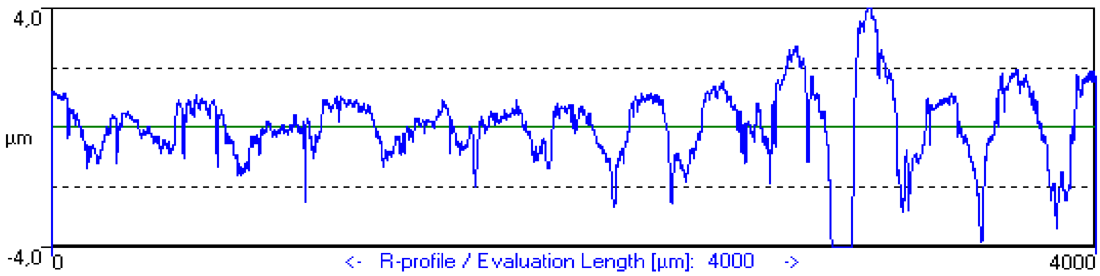
File: VP3_oil Profile no.: 2 Specimenmark: 0393341 15-06-2010



Ra 0,723
Rz 4,690
Rzmax 6,490

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

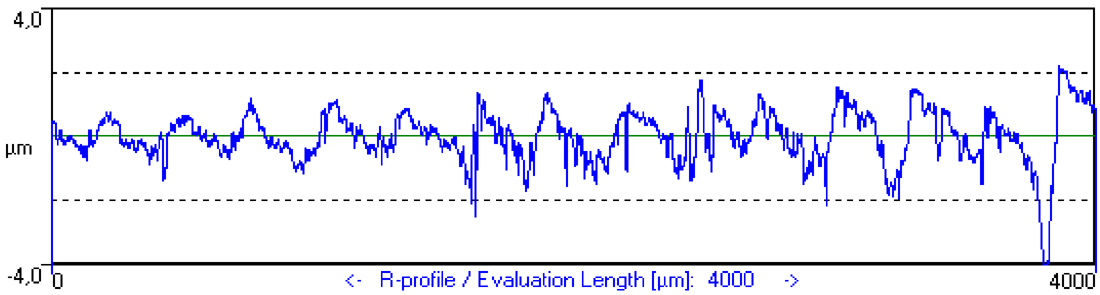
File: VP3_oil Profile no.: 3 Specimenmark: 0393341 15-06-2010



Ra 0,991
Rz 5,770
Rzmax 13,030

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: VP3_oil Profile no.: 4 Specimenmark: 0393341 15-06-2010



Ra 0,601
Rz 4,092
Rzmax 7,510

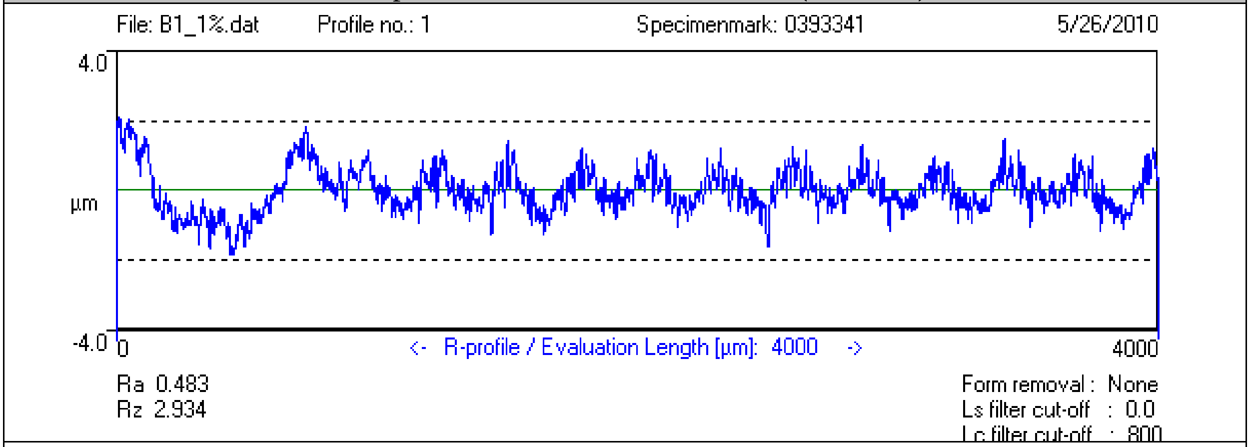
Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

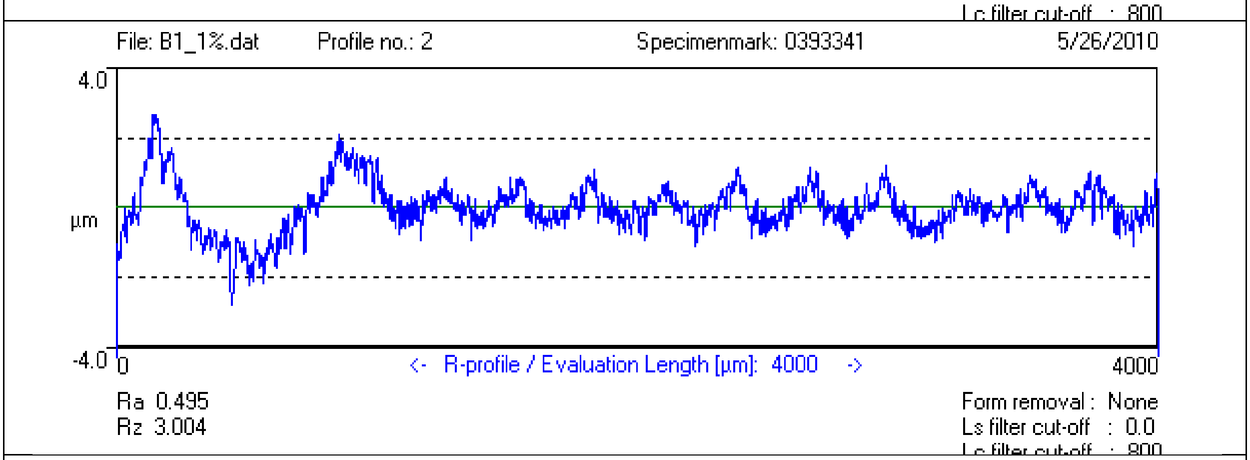
Appendix J3: Surface roughness measurement

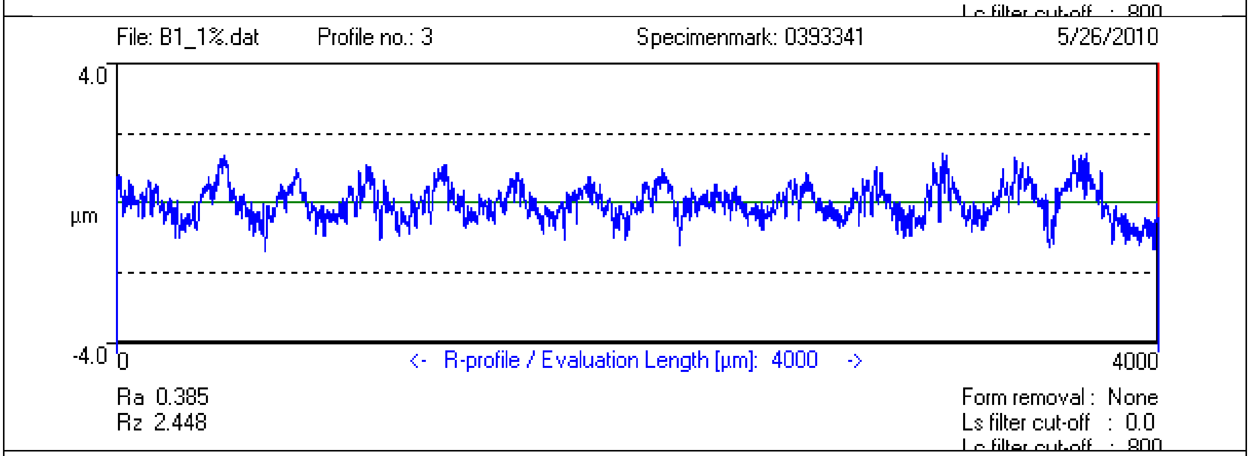
Operator C: 19/04-2010

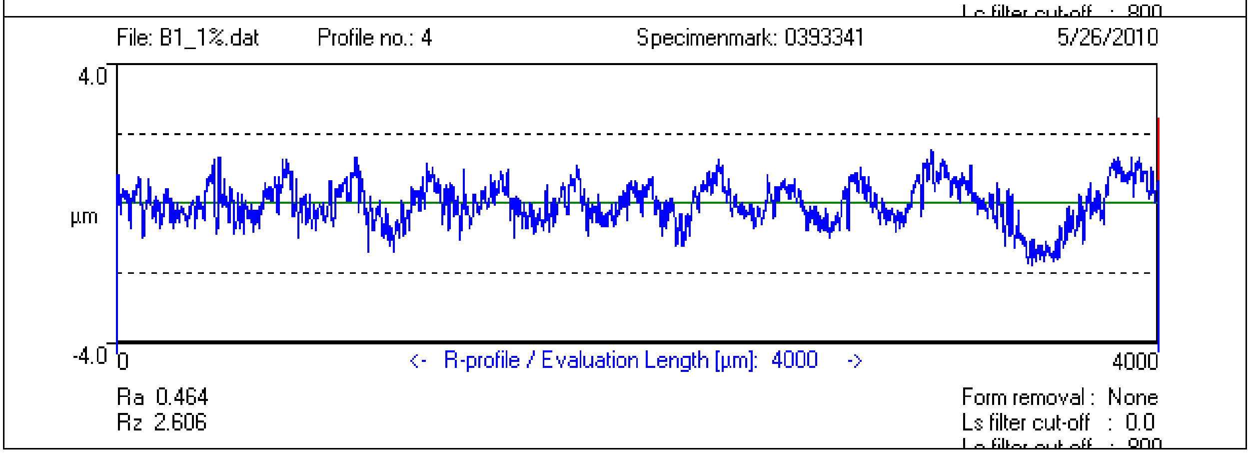
Operator C – 19/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P1 – 1% oil concentration (P0.3/W1)





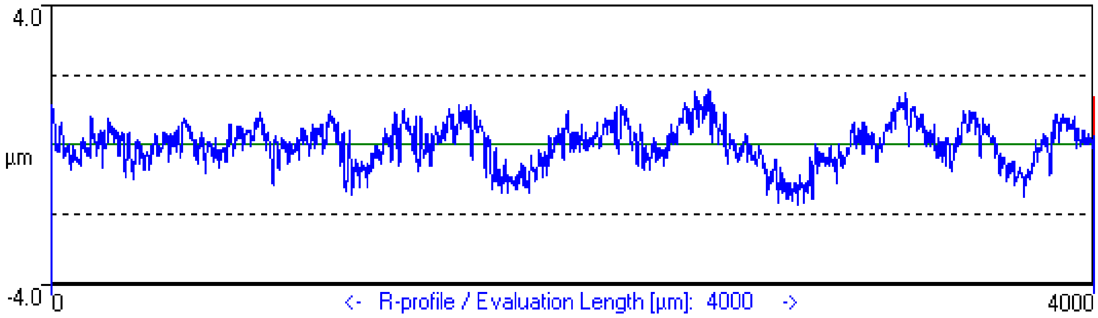




Operator C – 19/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P2 – 1% oil concentration (P0.3/W1)

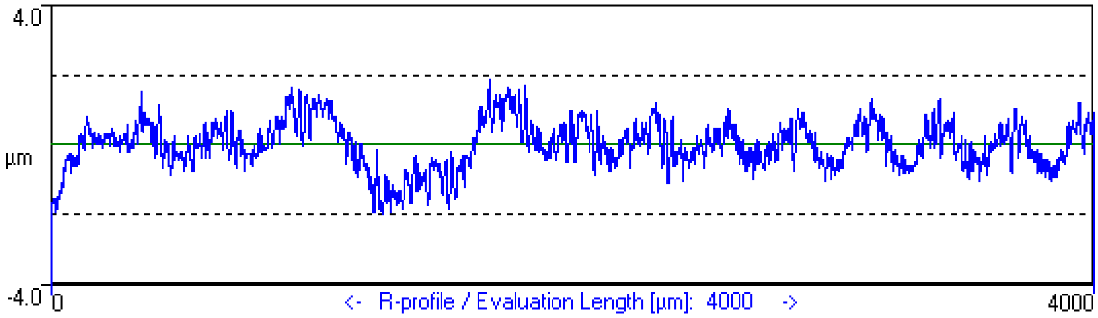
File: B2_1%.dat Profile no.: 1 Specimenmark: 0393341 5/26/2010



Ra 0.463
Rz 2.694

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

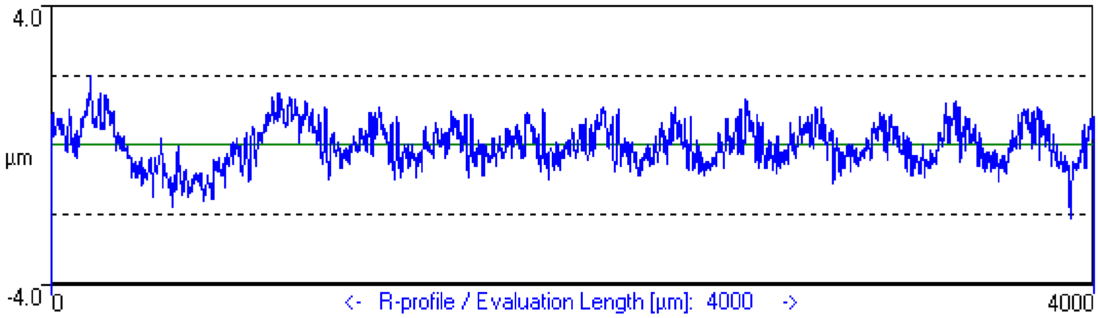
File: B2_1%.dat Profile no.: 2 Specimenmark: 0393341 5/26/2010



Ra 0.526
Rz 2.962

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

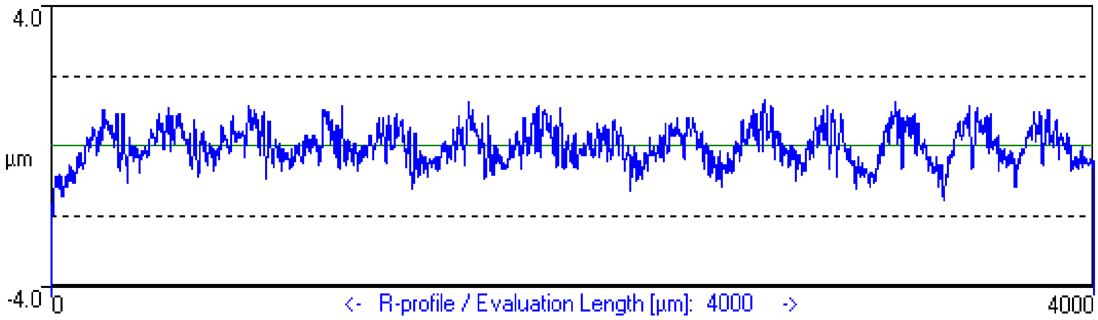
File: B2_1%.dat Profile no.: 3 Specimenmark: 0393341 5/26/2010



Ra 0.468
Rz 2.792

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: B2_1%.dat Profile no.: 4 Specimenmark: 0393341 5/26/2010



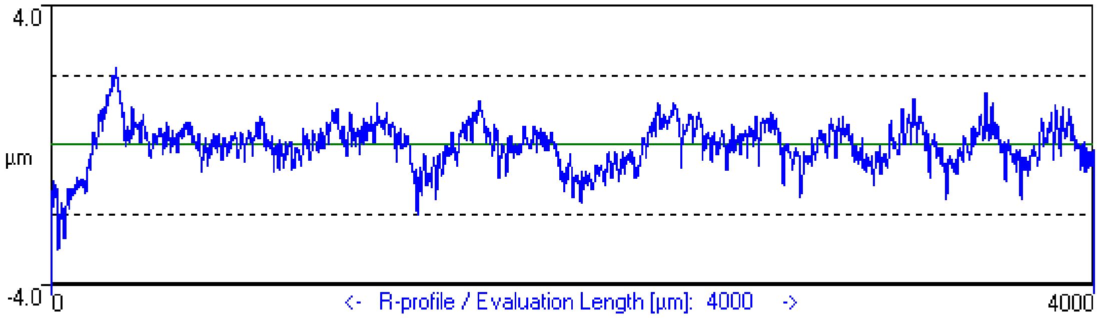
Ra 0.417
Rz 2.662

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

Operator C – 19/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P3 – 1% oil concentration (P0.3/W1)

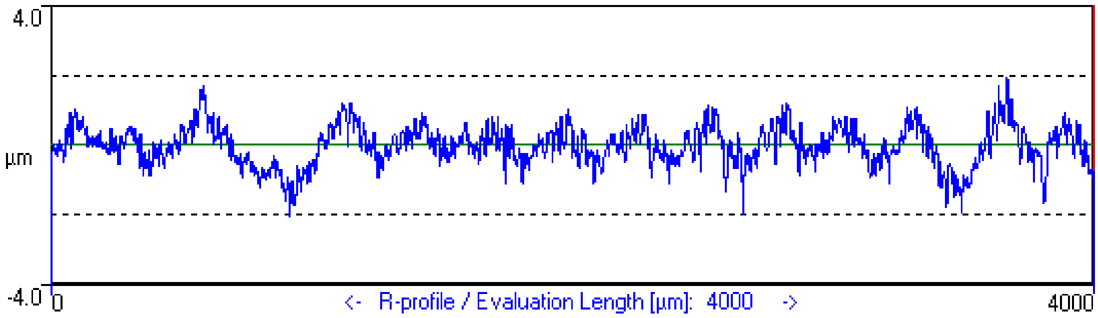
File: B3_1%.dat Profile no.: 1 Specimenmark: 0393341 5/26/2010



Ra 0.476
Rz 3.336

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

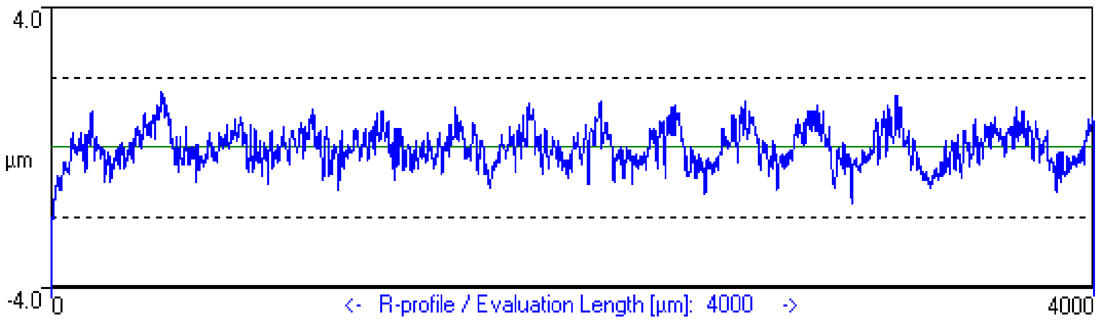
File: B3_1%.dat Profile no.: 2 Specimenmark: 0393341 5/26/2010



Ra 0.444
Rz 3.054

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

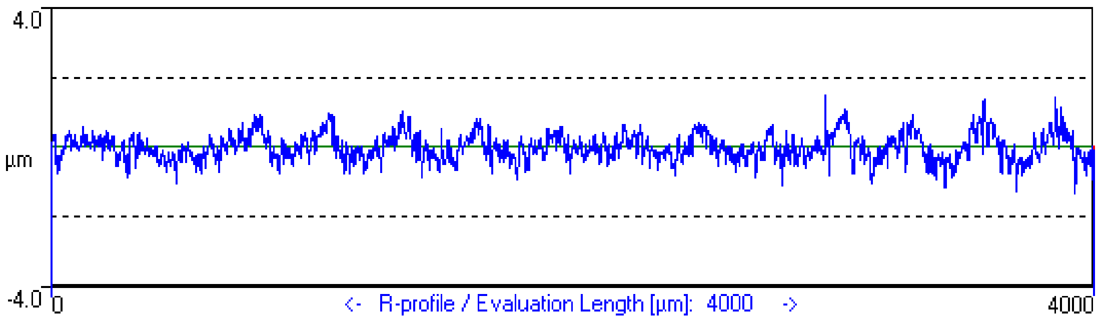
File: B3_1%.dat Profile no.: 3 Specimenmark: 0393341 5/26/2010



Ra 0.420
Rz 2.846

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: B3_1%.dat Profile no.: 4 Specimenmark: 0393341 5/26/2010



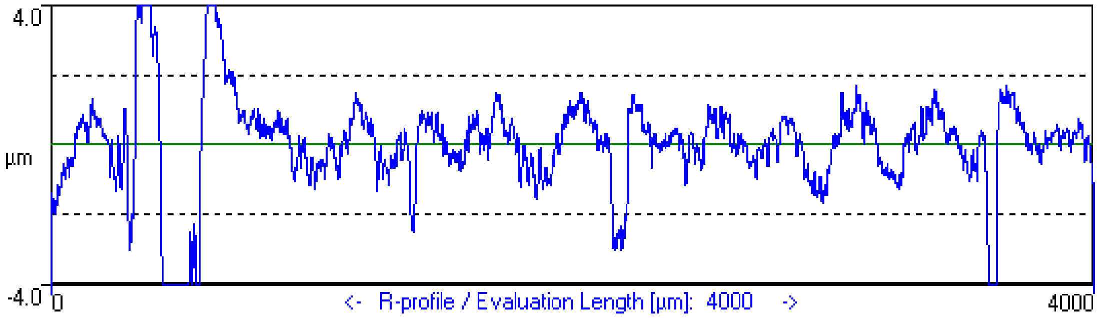
Ra 0.302
Rz 2.176

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

Operator C – 19/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R1 – 1% oil concentration (R0.3/W1)

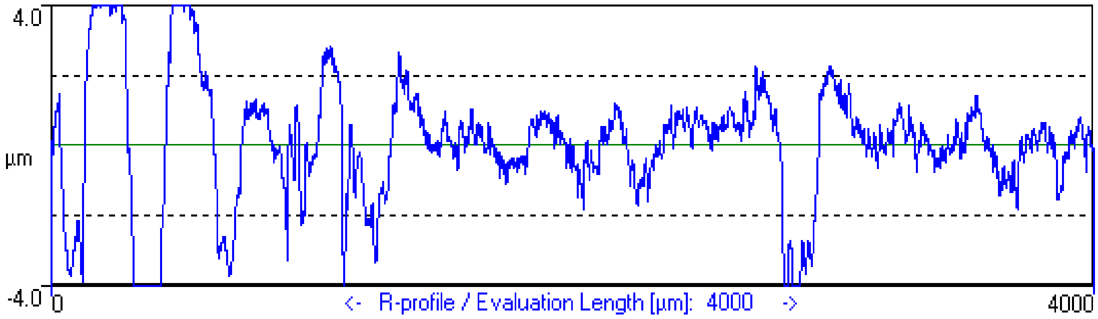
File: R1_1%.dat Profile no.: 1 Specimenmark: 0393341 5/26/2010



Ra 0.990
Rz 6.752

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

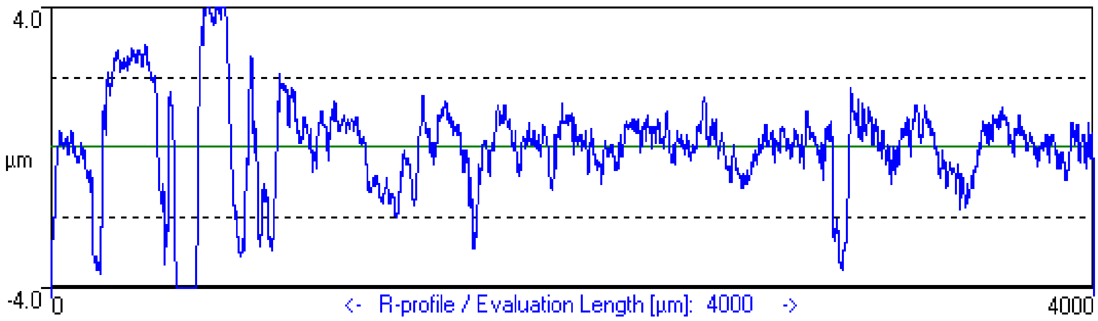
File: R1_1%.dat Profile no.: 2 Specimenmark: 0393341 5/26/2010



Ra 1.318
Rz 7.284

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

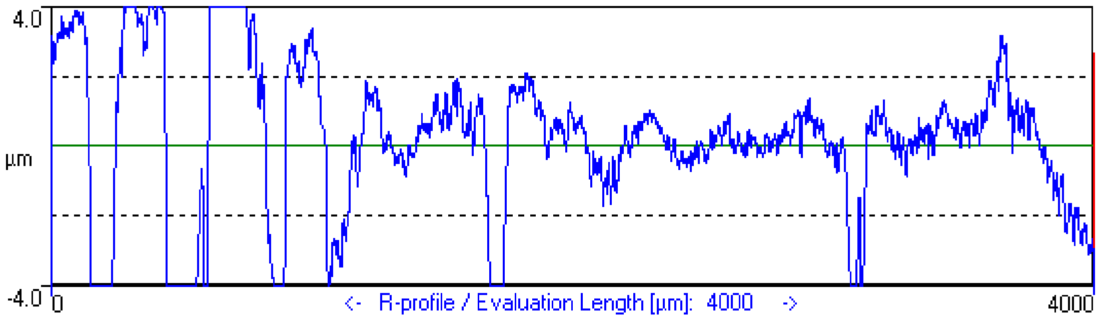
File: R1_1%.dat Profile no.: 3 Specimenmark: 0393341 5/26/2010



Ra 0.986
Rz 6.302

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: R1_1%.dat Profile no.: 4 Specimenmark: 0393341 5/26/2010



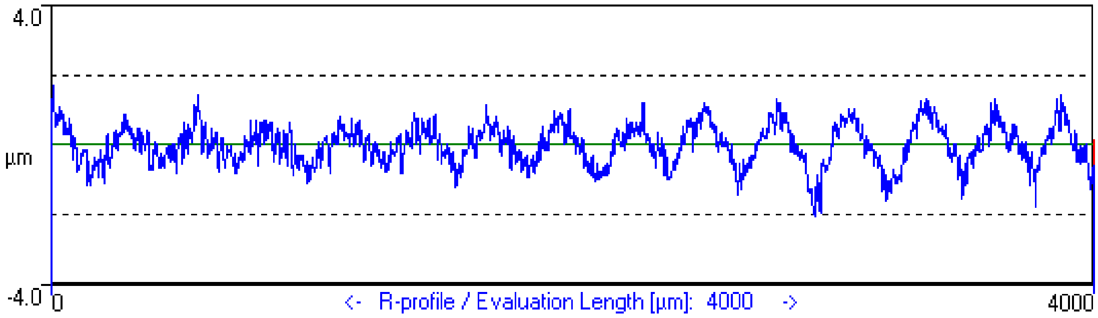
Ra 1.936
Rz 12.204

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

Operator C – 19/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R2 – 1% oil concentration (R0.3/W1)

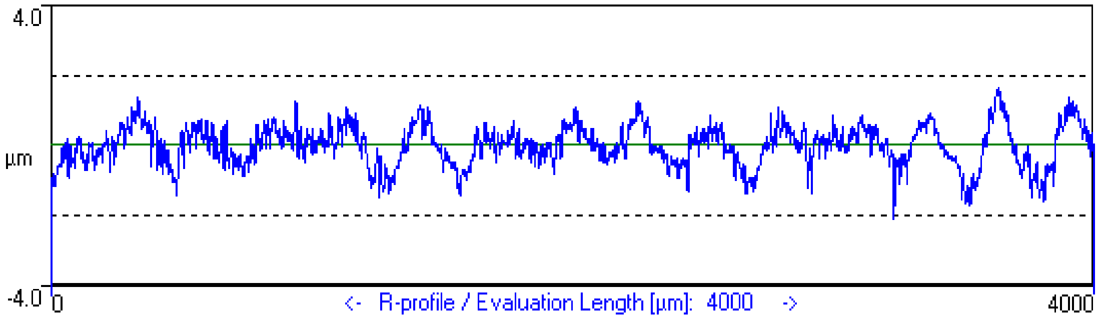
File: R2_1%.dat Profile no.: 1 Specimenmark: 0393341 5/26/2010



Ra 0.460
Rz 2.736

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

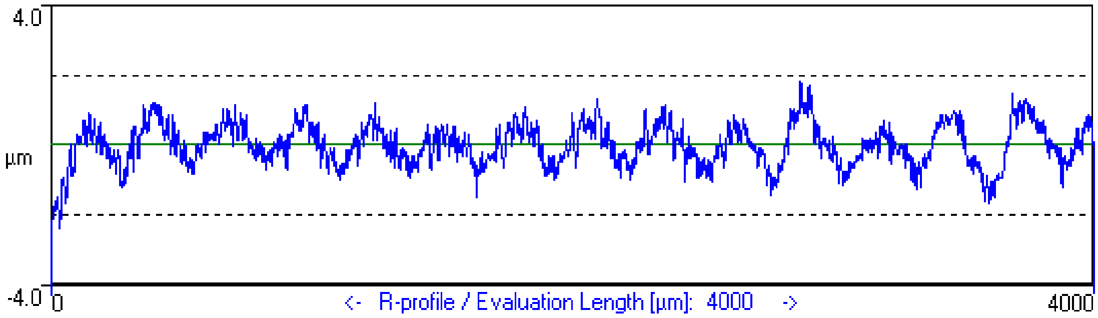
File: R2_1%.dat Profile no.: 2 Specimenmark: 0393341 5/26/2010



Ra 0.455
Rz 2.776

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

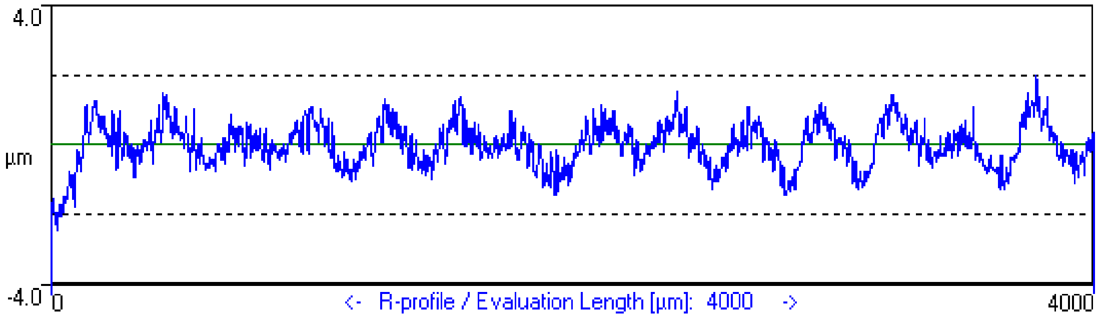
File: R2_1%.dat Profile no.: 3 Specimenmark: 0393341 5/26/2010



Ra 0.478
Rz 3.006

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: R2_1%.dat Profile no.: 4 Specimenmark: 0393341 5/26/2010

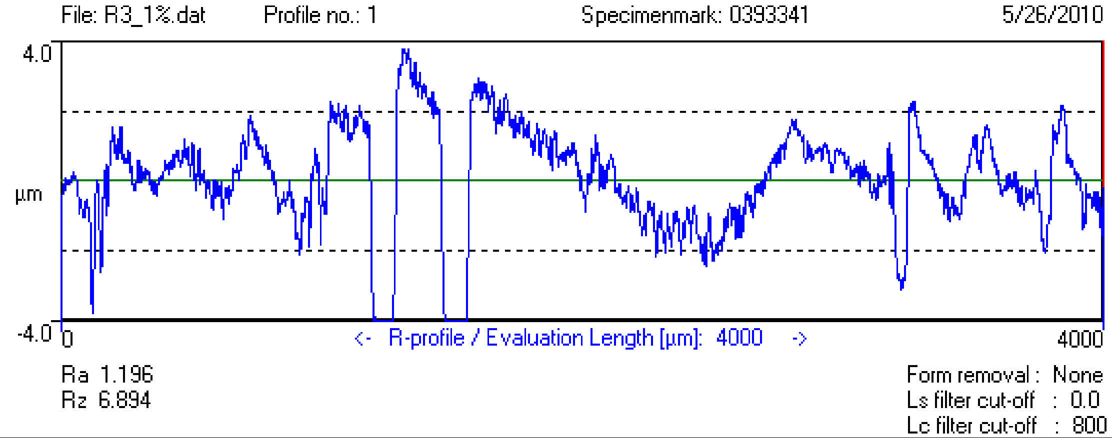


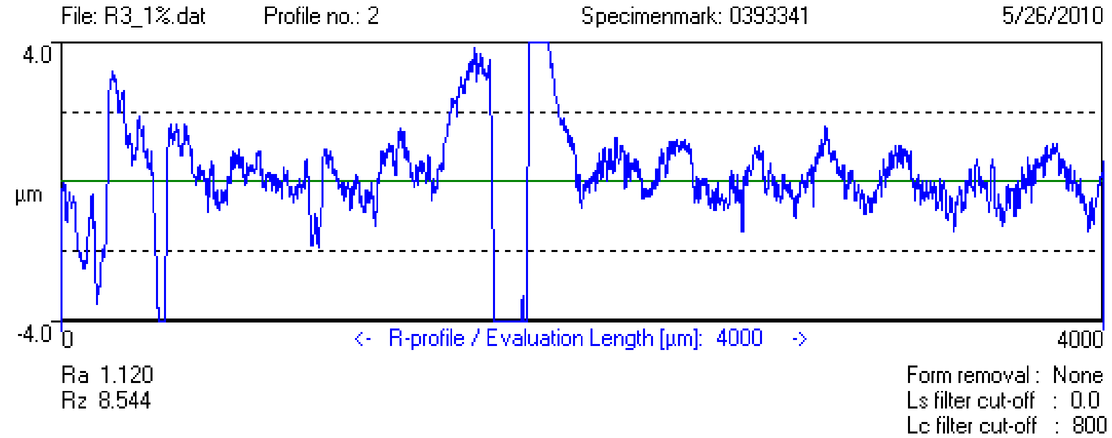
Ra 0.493
Rz 3.054

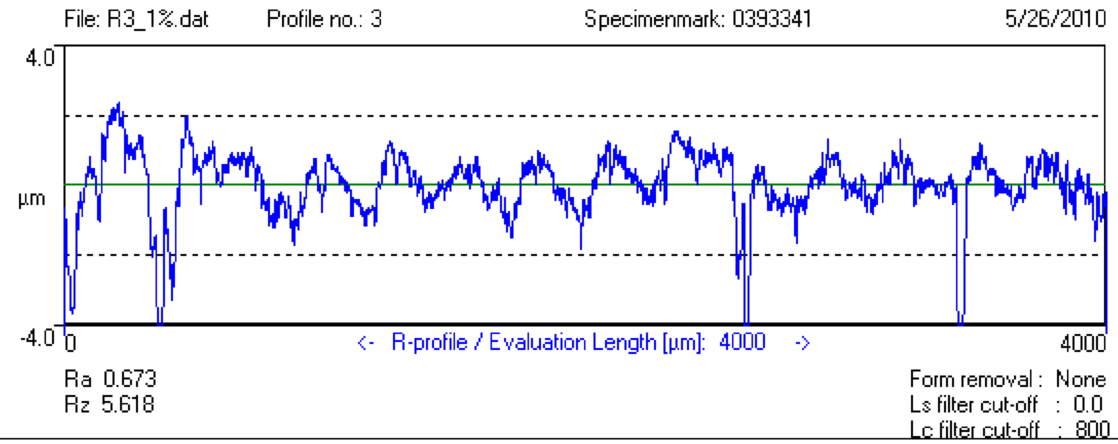
Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

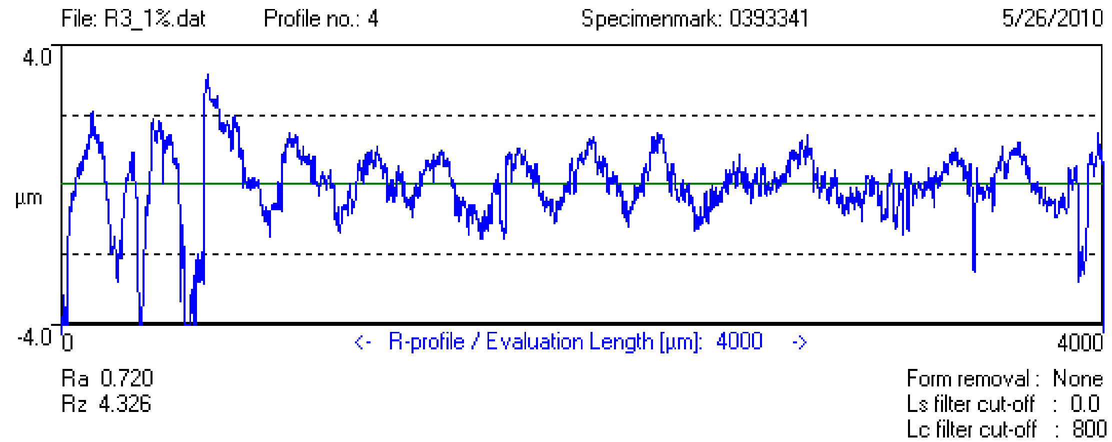
Operator C – 19/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R3 – 1% oil concentration (R0.3/W1)





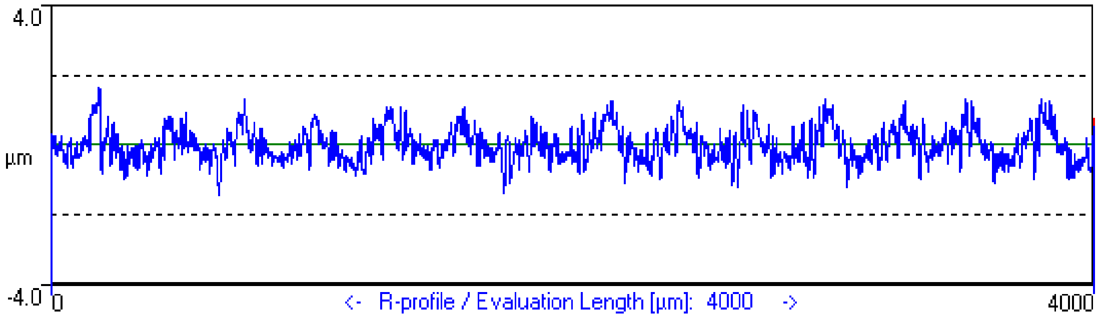




Operator C – 19/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P1 – 10% oil concentration (P0.3/W2)

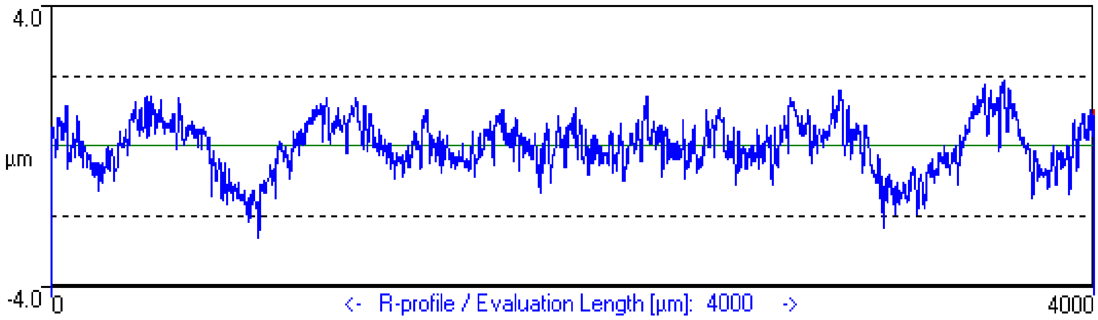
File: B1_10%.dat   Profile no.: 1   Specimenmark: 0393341   5/26/2010



Ra 0.383
Rz 2.522

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

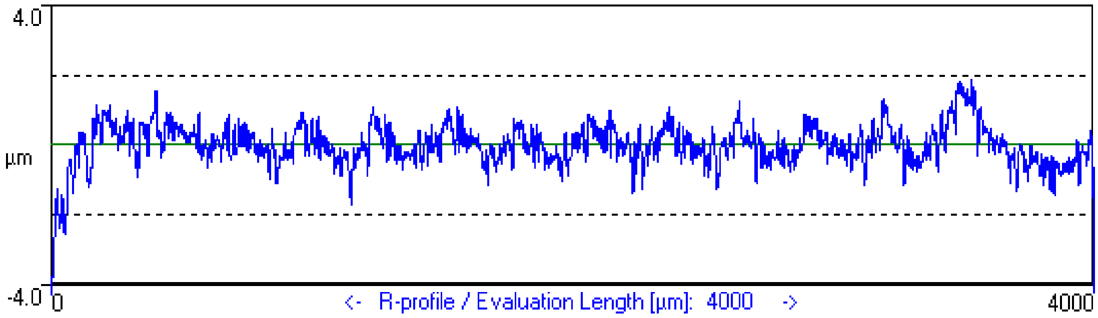
File: B1_10%.dat   Profile no.: 2   Specimenmark: 0393341   5/26/2010



Ra 0.571
Rz 3.478

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

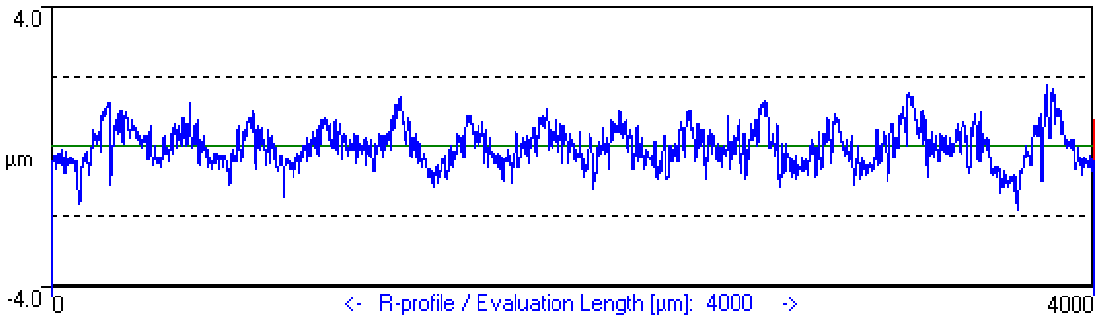
File: B1_10%.dat   Profile no.: 3   Specimenmark: 0393341   5/26/2010



Ra 0.433
Rz 3.328

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: B1_10%.dat   Profile no.: 4   Specimenmark: 0393341   5/26/2010



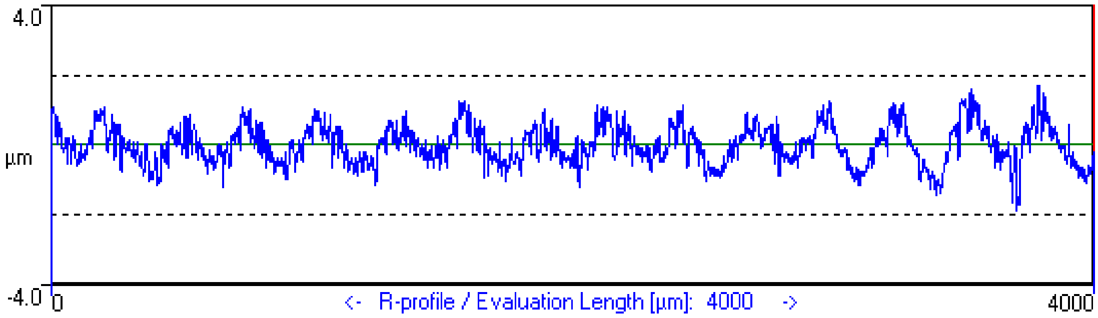
Ra 0.429
Rz 2.836

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

Operator C – 19/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P2 – 10% oil concentration (P0.3/W2)

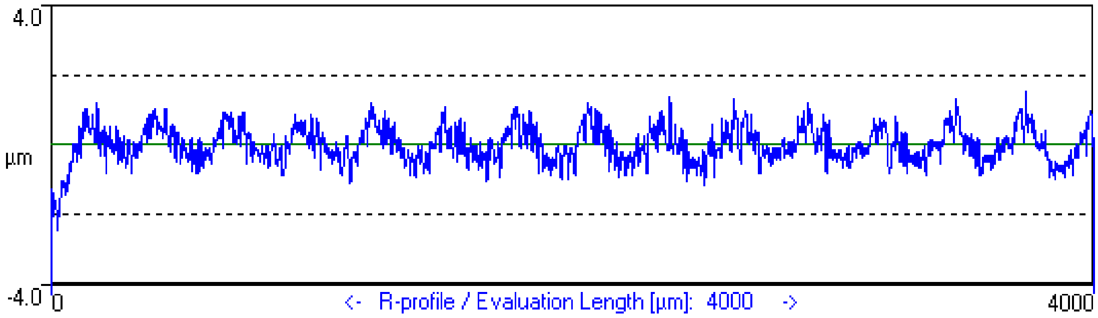
File: B2_10%.dat   Profile no.: 1   Specimenmark: 0393341   5/26/2010



Ra 0.440
Rz 2.604

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

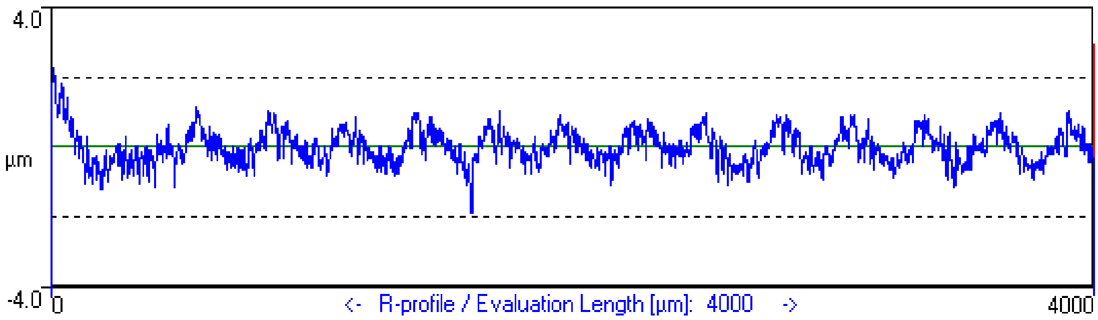
File: B2_10%.dat   Profile no.: 2   Specimenmark: 0393341   5/26/2010



Ra 0.402
Rz 2.660

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

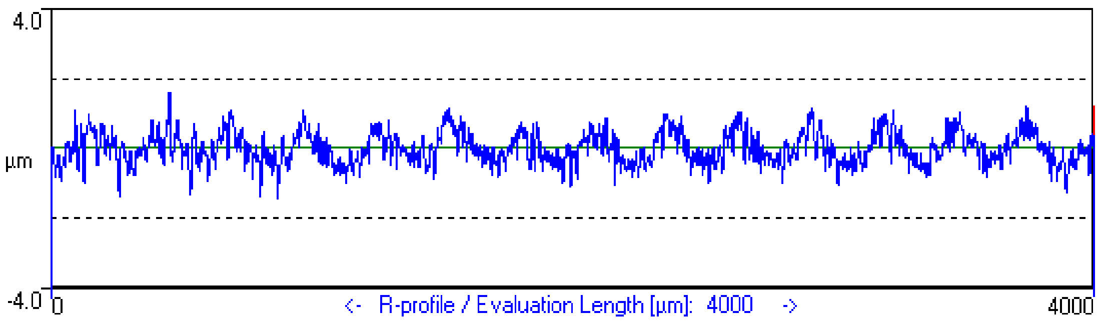
File: B2_10%.dat   Profile no.: 3   Specimenmark: 0393341   5/26/2010



Ra 0.375
Rz 2.542

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: B2_10%.dat   Profile no.: 4   Specimenmark: 0393341   5/26/2010



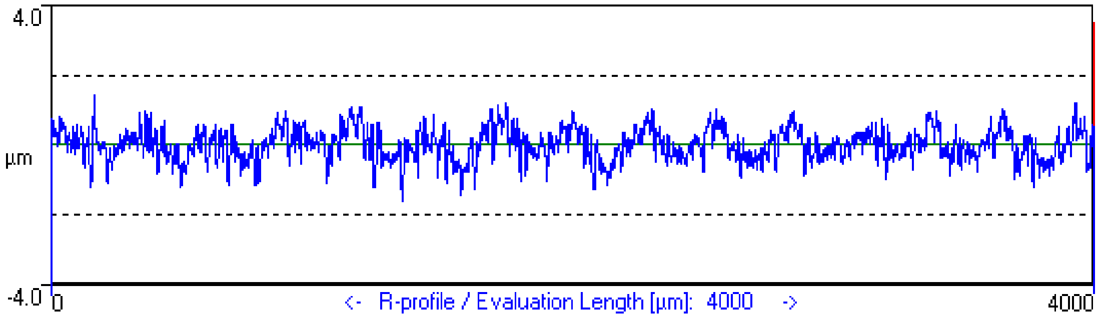
Ra 0.366
Rz 2.450

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

Operator C – 19/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P3 – 10% oil concentration (P0.3/W2)

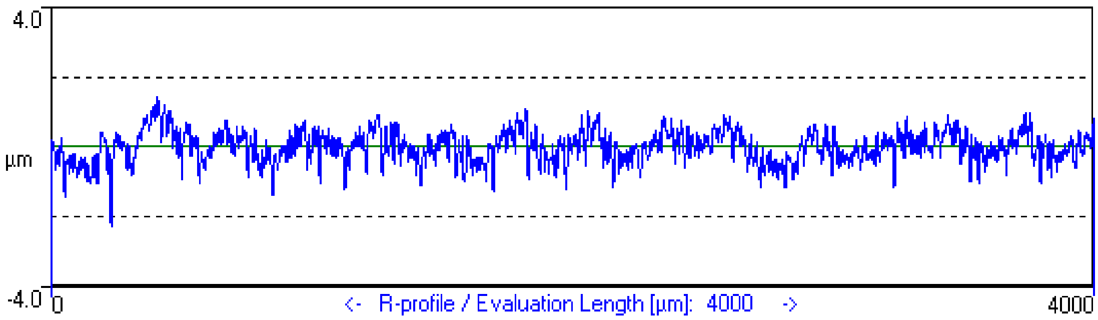
File: B3_10%.dat Profile no.: 1 Specimenmark: 0393341 5/26/2010



Ra 0.368
Rz 2.446

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

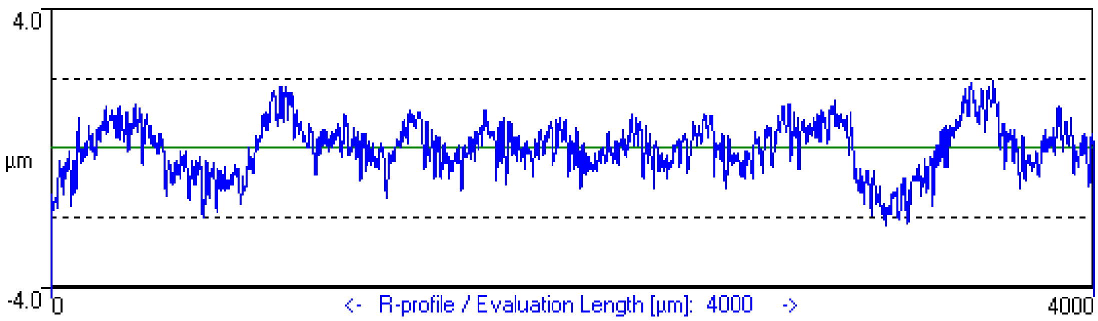
File: B3_10%.dat Profile no.: 2 Specimenmark: 0393341 5/26/2010



Ra 0.359
Rz 2.504

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

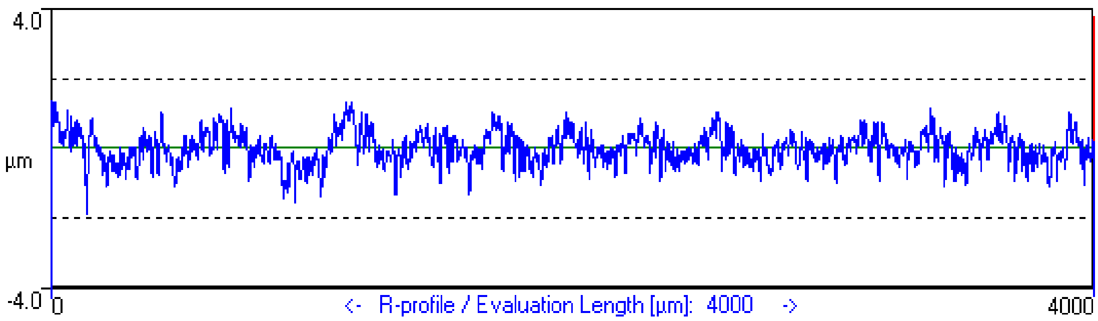
File: B3_10%.dat Profile no.: 3 Specimenmark: 0393341 5/26/2010



Ra 0.583
Rz 3.248

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: B3_10%.dat Profile no.: 4 Specimenmark: 0393341 5/26/2010



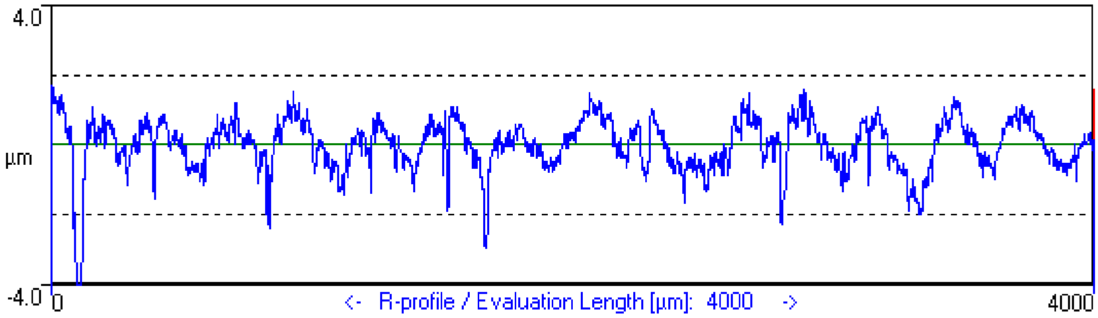
Ra 0.360
Rz 2.540

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

Operator C – 19/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R1 – 10% oil concentration (R0.3/W2)

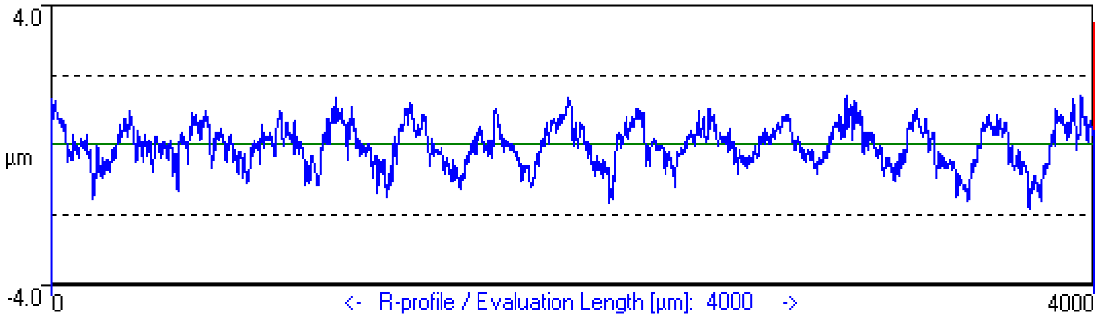
File: R1_10%.dat Profile no.: 1 Specimenmark: 0393341 5/26/2010



Ra 0.569
Rz 4.360

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

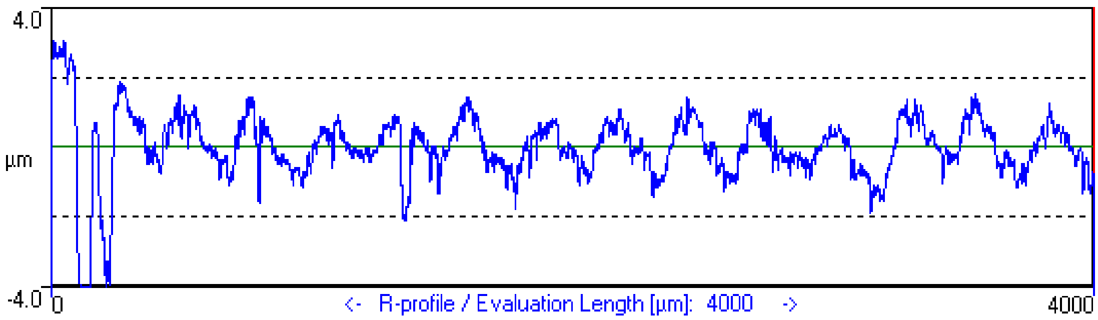
File: R1_10%.dat Profile no.: 2 Specimenmark: 0393341 5/26/2010



Ra 0.476
Rz 2.862

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

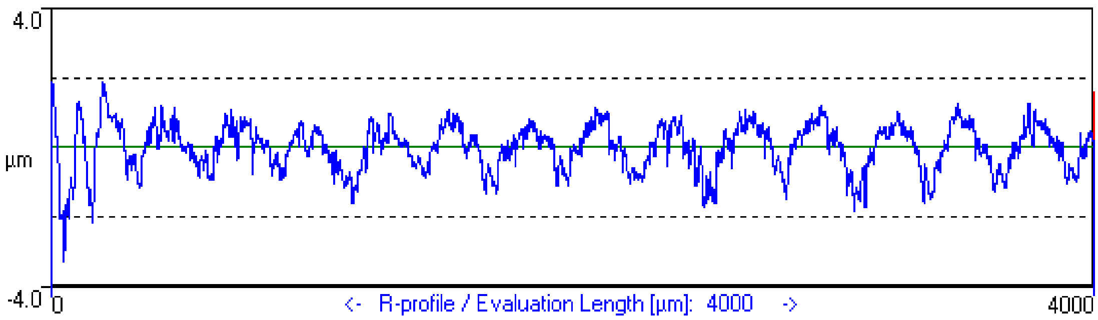
File: R1_10%.dat Profile no.: 3 Specimenmark: 0393341 5/26/2010



Ra 0.681
Rz 4.392

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: R1_10%.dat Profile no.: 4 Specimenmark: 0393341 5/26/2010



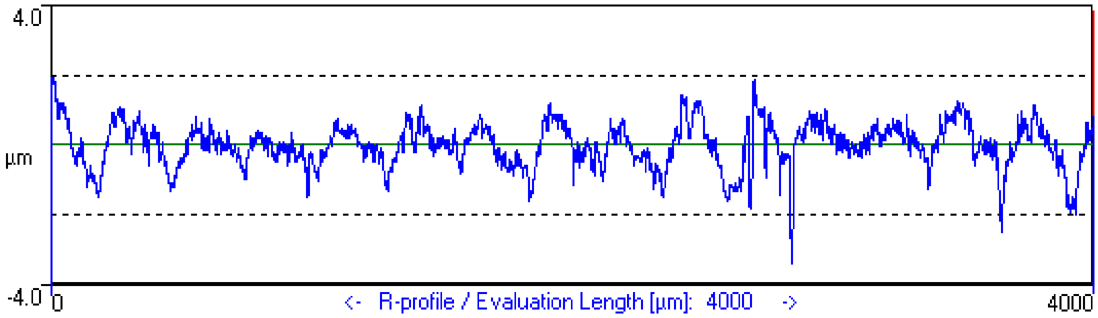
Ra 0.541
Rz 3.228

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

Operator C – 19/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R2 – 10% oil concentration (R0.3/W2)

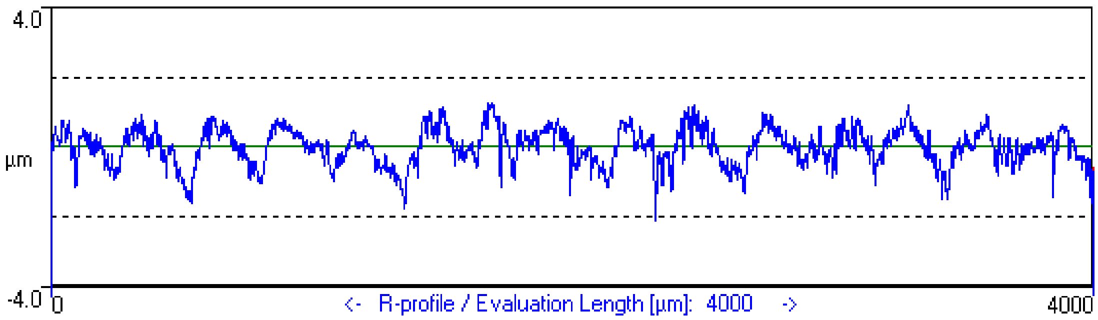
File: R2_10%.dat Profile no.: 1 Specimenmark: 0393341 5/26/2010



Ra 0.489
Rz 3.554

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

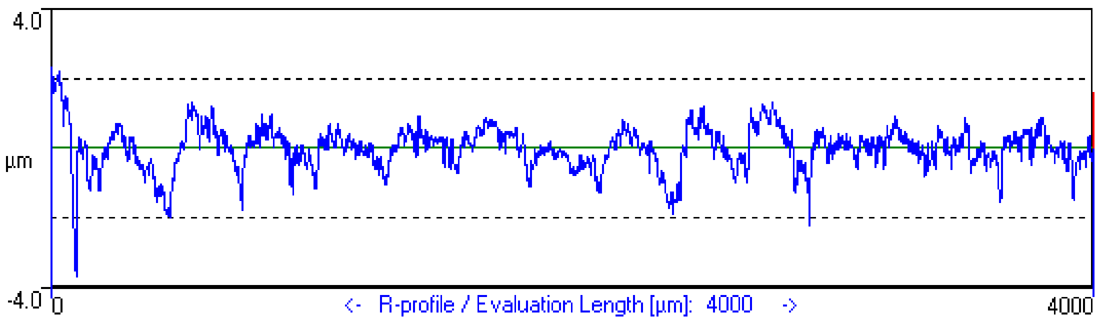
File: R2_10%.dat Profile no.: 2 Specimenmark: 0393341 5/26/2010



Ra 0.416
Rz 2.818

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

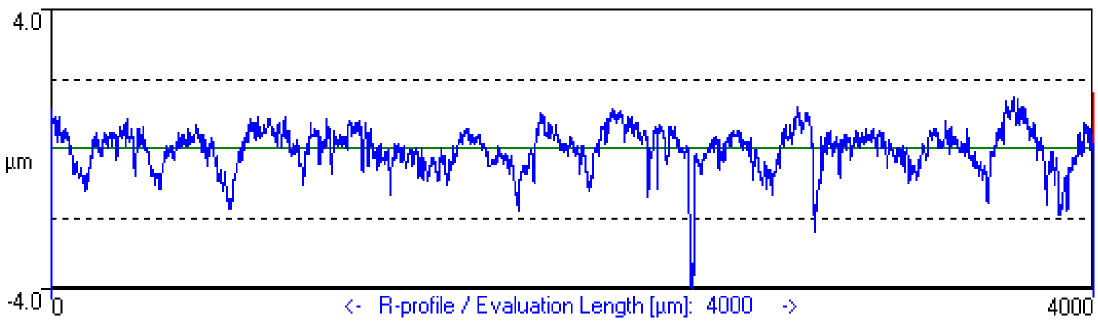
File: R2_10%.dat Profile no.: 3 Specimenmark: 0393341 5/26/2010



Ra 0.452
Rz 3.396

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: R2_10%.dat Profile no.: 4 Specimenmark: 0393341 5/26/2010



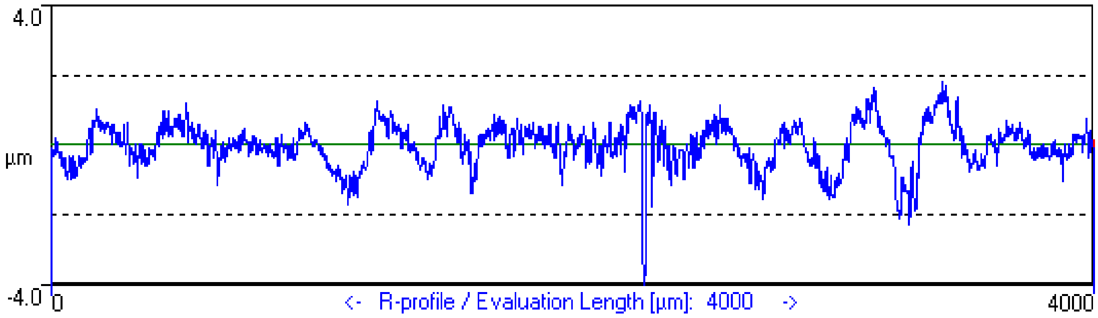
Ra 0.447
Rz 3.400

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

Operator C – 19/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R3 – 10% oil concentration (R0.3/W2)

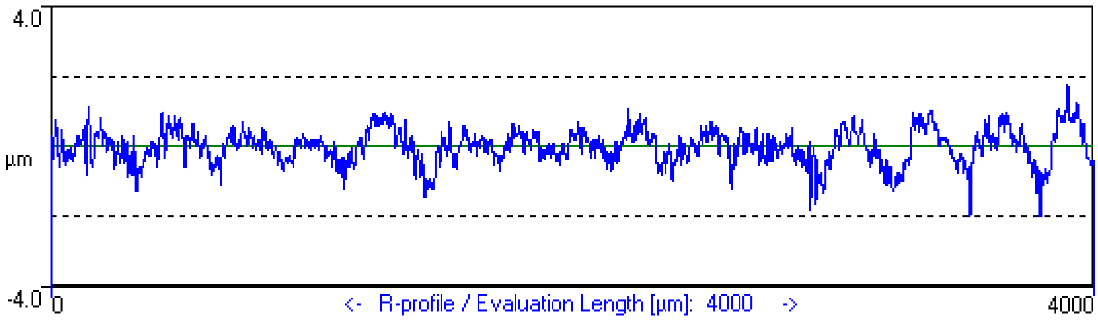
File: R3_10%.dat Profile no.: 1 Specimenmark: 0393341 5/26/2010



Ra 0.479
Rz 3.602

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

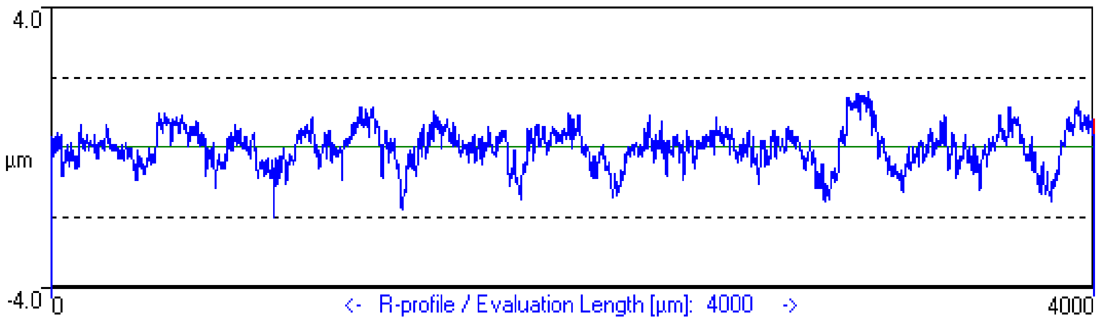
File: R3_10%.dat Profile no.: 2 Specimenmark: 0393341 5/26/2010



Ra 0.376
Rz 2.656

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

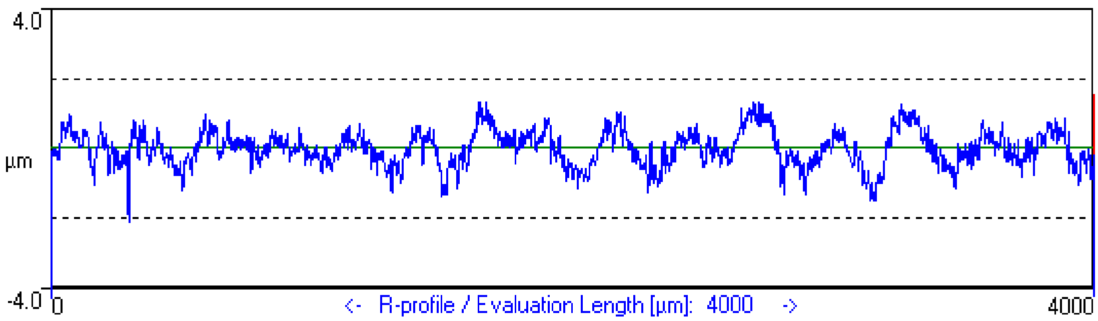
File: R3_10%.dat Profile no.: 3 Specimenmark: 0393341 5/26/2010



Ra 0.432
Rz 2.748

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: R3_10%.dat Profile no.: 4 Specimenmark: 0393341 5/26/2010



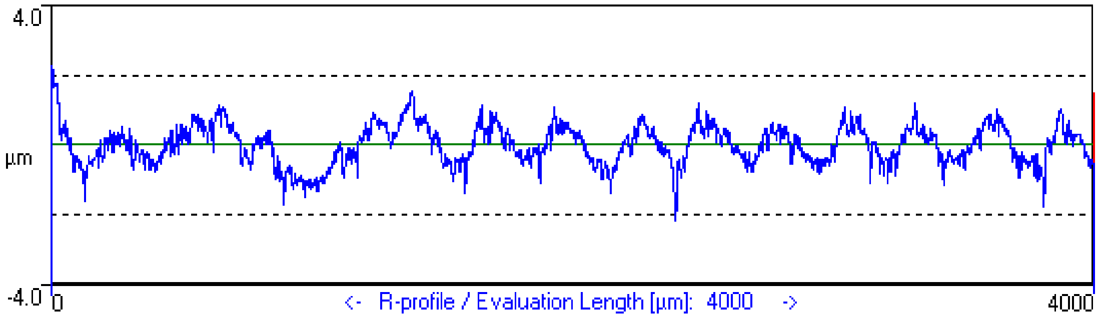
Ra 0.403
Rz 2.588

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

Operator C – 19/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P1 – OIL (P0.3/M)

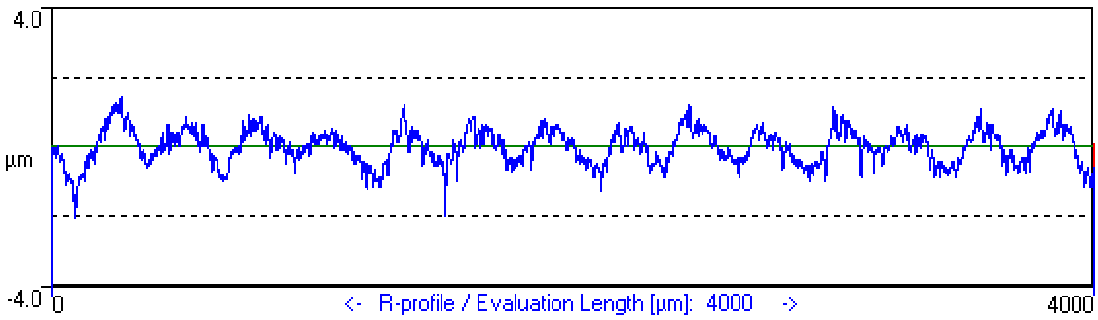
File: B1_OIL.dat   Profile no.: 1   Specimenmark: 0393341   5/26/2010



Ra 0.458
Rz 3.164

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

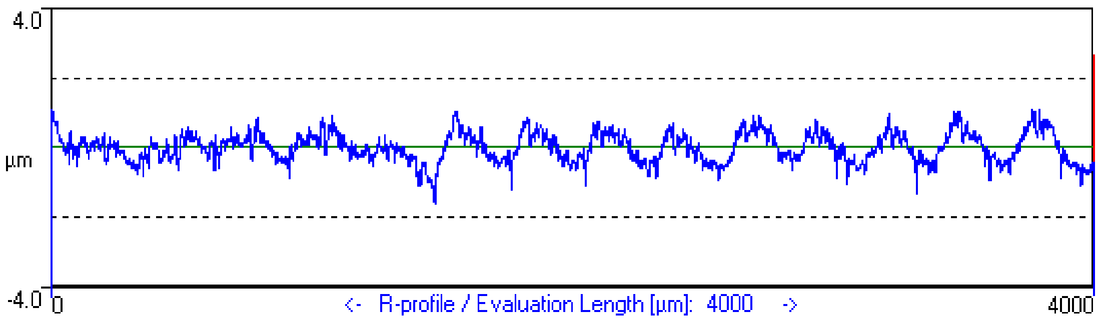
File: B1_OIL.dat   Profile no.: 2   Specimenmark: 0393341   5/26/2010



Ra 0.402
Rz 2.644

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

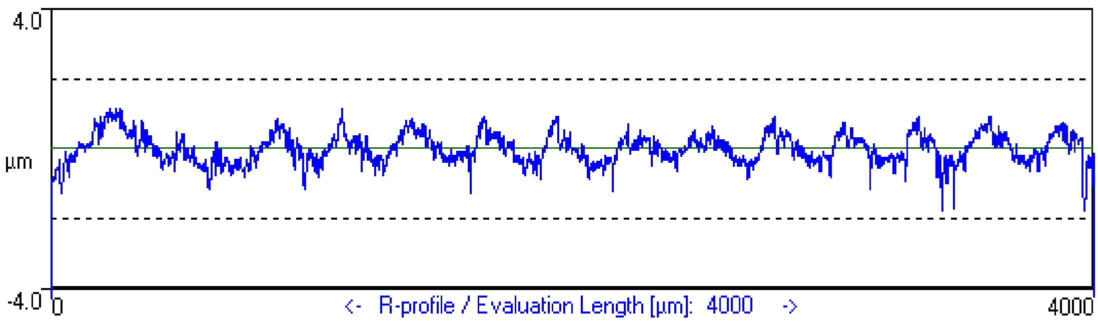
File: B1_OIL.dat   Profile no.: 3   Specimenmark: 0393341   5/26/2010



Ra 0.340
Rz 2.190

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: B1_OIL.dat   Profile no.: 4   Specimenmark: 0393341   5/26/2010



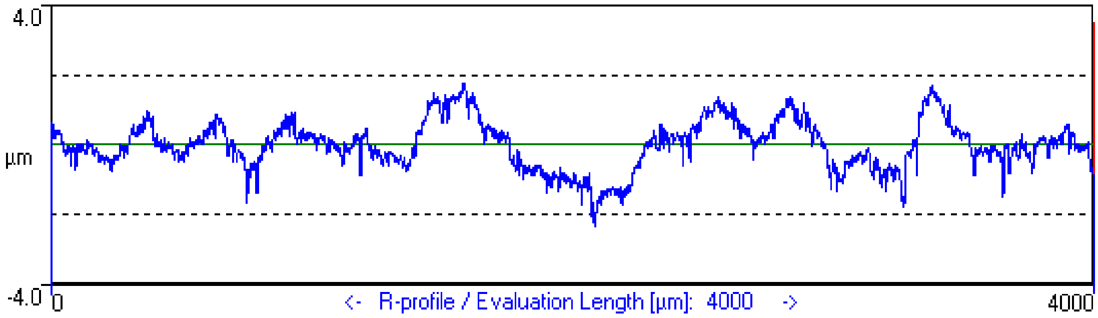
Ra 0.344
Rz 2.324

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

Operator C – 19/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P2 – OIL (P0.3/M)

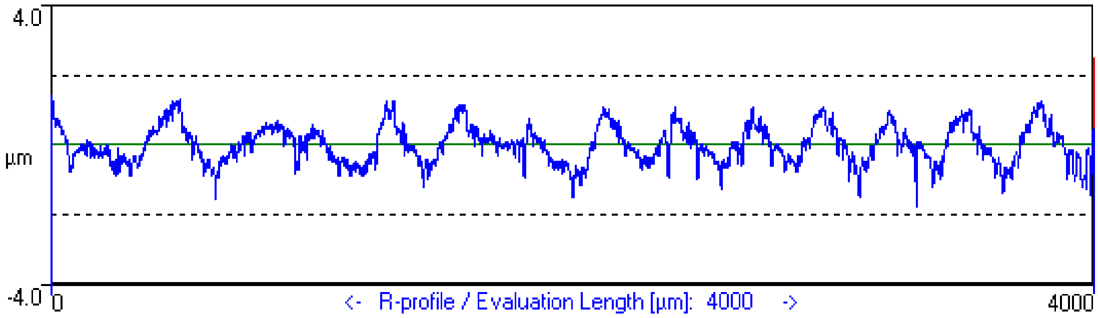
File: B2_OIL.dat Profile no.: 1 Specimenmark: 0393341 5/26/2010



Ra 0.535
Rz 3.052

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

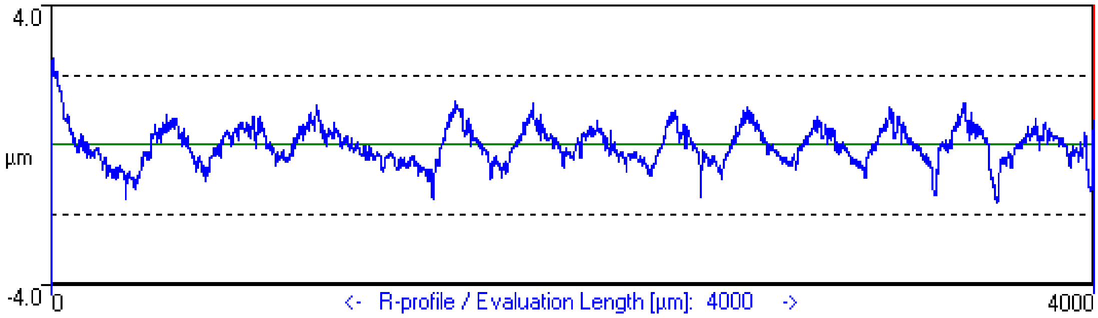
File: B2_OIL.dat Profile no.: 2 Specimenmark: 0393341 5/26/2010



Ra 0.439
Rz 2.716

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

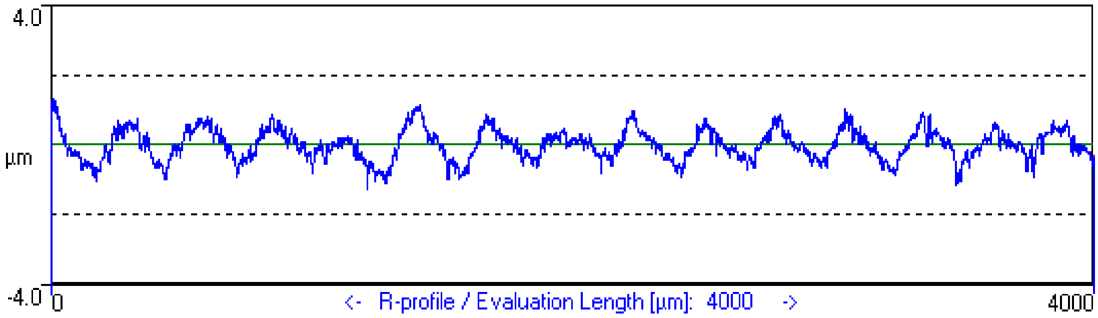
File: B2_OIL.dat Profile no.: 3 Specimenmark: 0393341 5/26/2010



Ra 0.424
Rz 2.888

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: B2_OIL.dat Profile no.: 4 Specimenmark: 0393341 5/26/2010



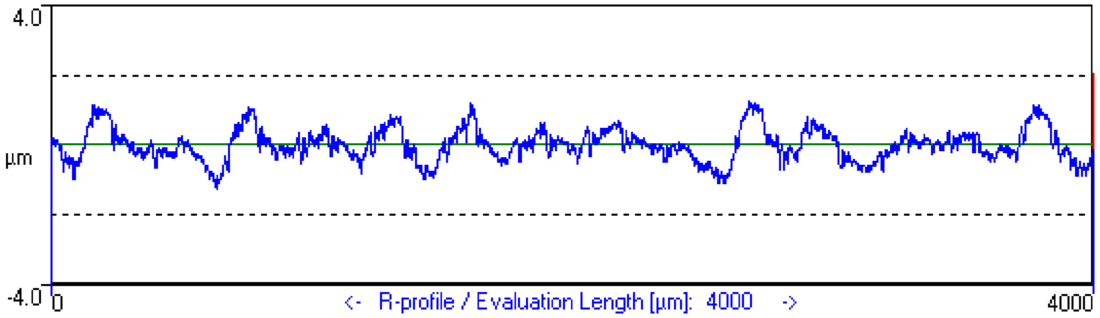
Ra 0.353
Rz 2.116

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

Operator C – 19/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P3 – OIL (P0.3/M)

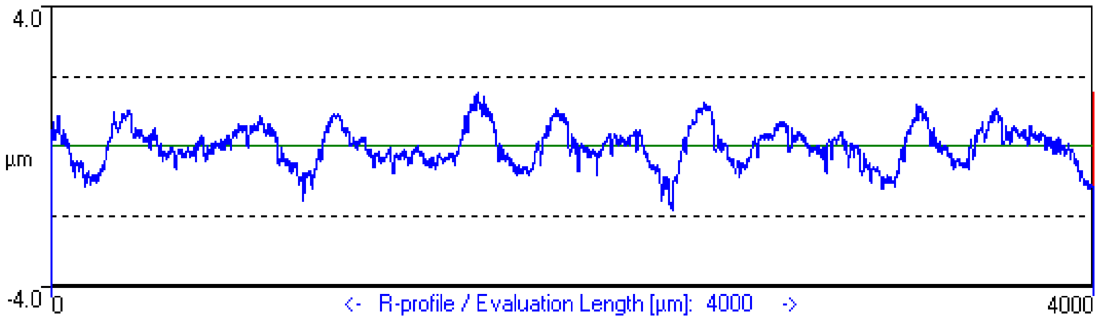
File: B3_OIL.dat Profile no.: 1 Specimenmark: 0393341 5/26/2010



Ra 0.354
Rz 2.086

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

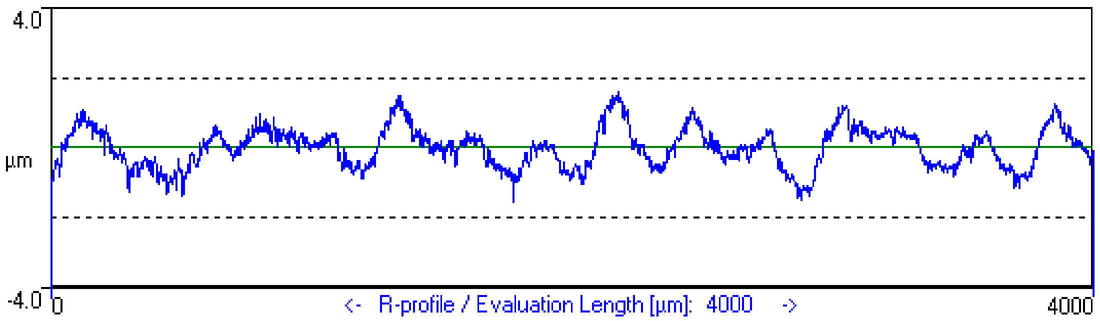
File: B3_OIL.dat Profile no.: 2 Specimenmark: 0393341 5/26/2010



Ra 0.437
Rz 2.592

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

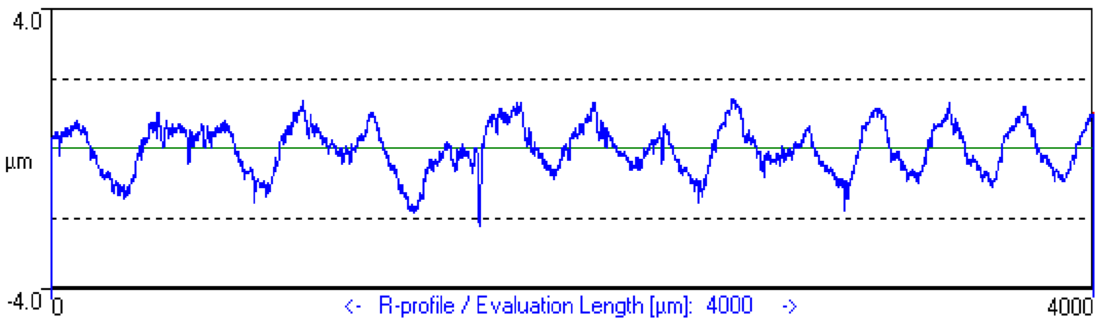
File: B3_OIL.dat Profile no.: 3 Specimenmark: 0393341 5/26/2010



Ra 0.459
Rz 2.606

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: B3_OIL.dat Profile no.: 4 Specimenmark: 0393341 5/26/2010



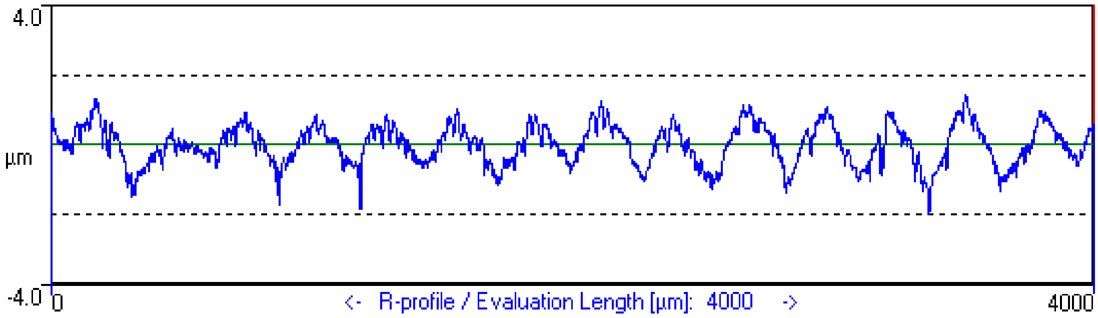
Ra 0.551
Rz 2.972

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

Operator C – 19/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R1 – OIL (R0.3/M)

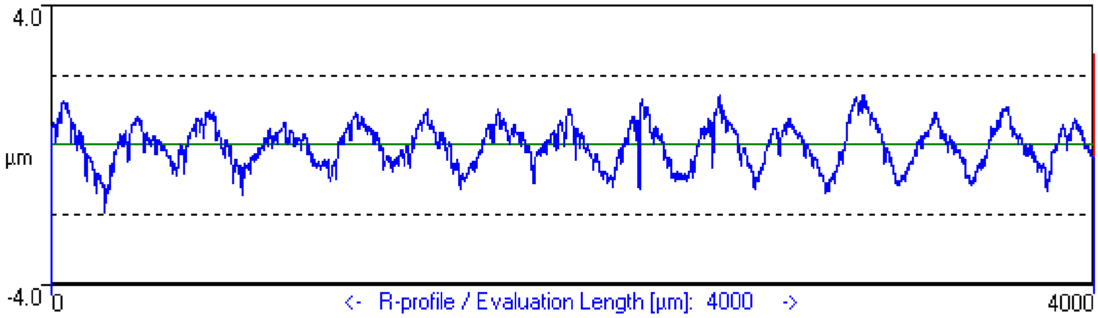
File: R1_OIL.dat Profile no.: 1 Specimenmark: 0393341 5/26/2010



Ra 0.465
Rz 2.778

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

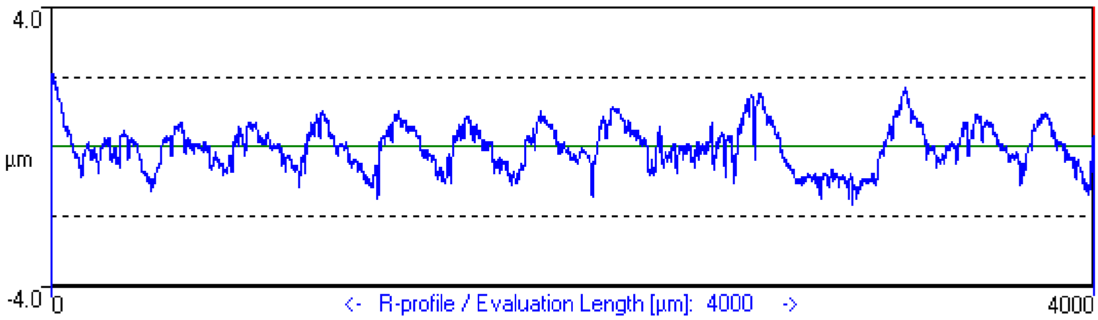
File: R1_OIL.dat Profile no.: 2 Specimenmark: 0393341 5/26/2010



Ra 0.484
Rz 2.628

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

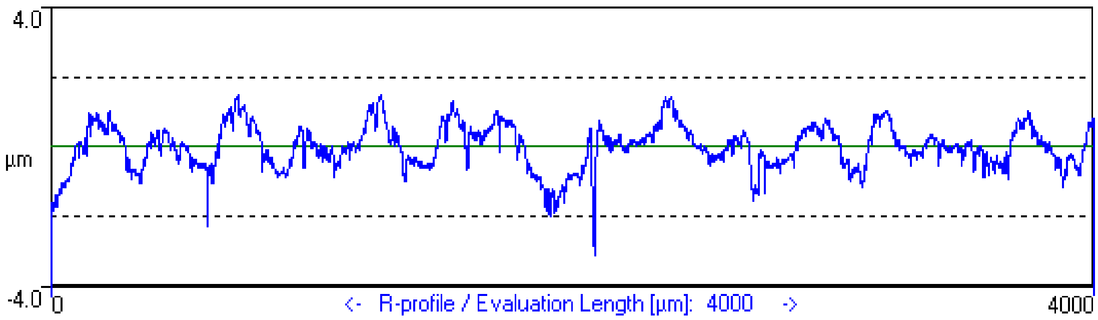
File: R1_OIL.dat Profile no.: 3 Specimenmark: 0393341 5/26/2010



Ra 0.497
Rz 2.944

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: R1_OIL.dat Profile no.: 4 Specimenmark: 0393341 5/26/2010

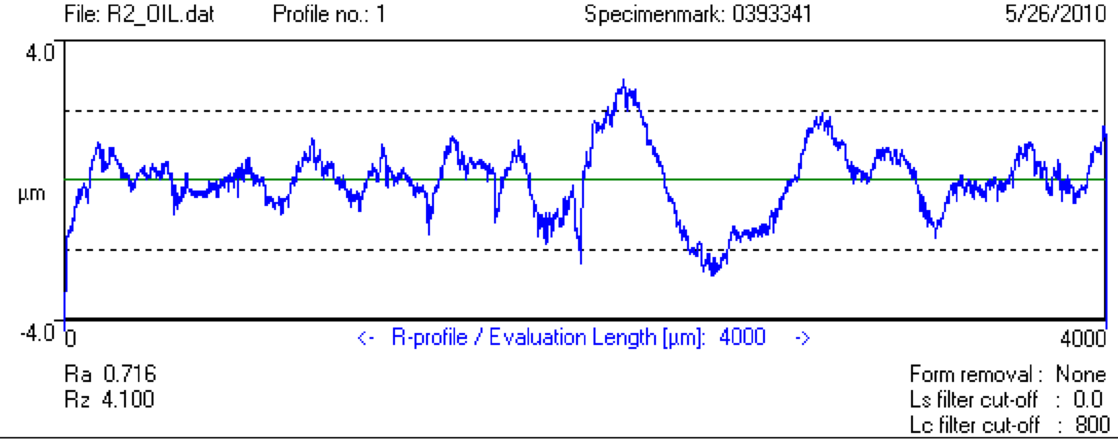


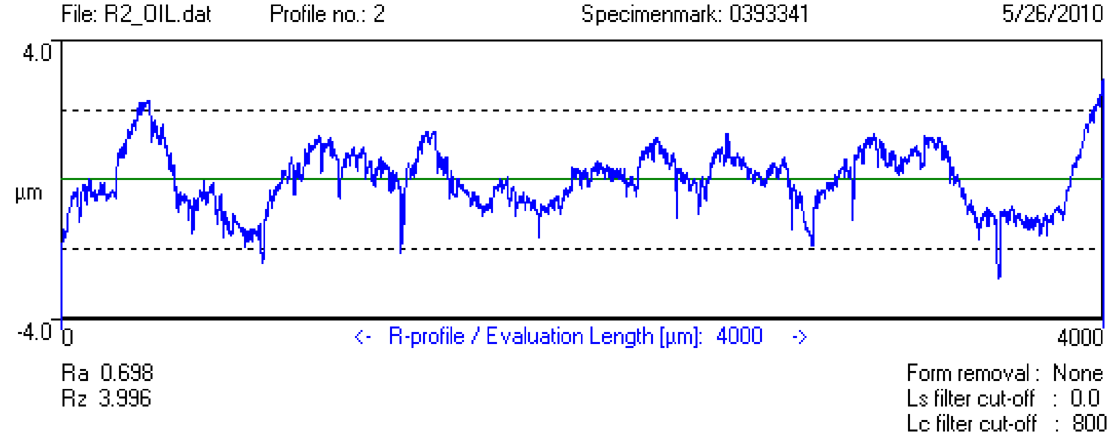
Ra 0.497
Rz 3.108

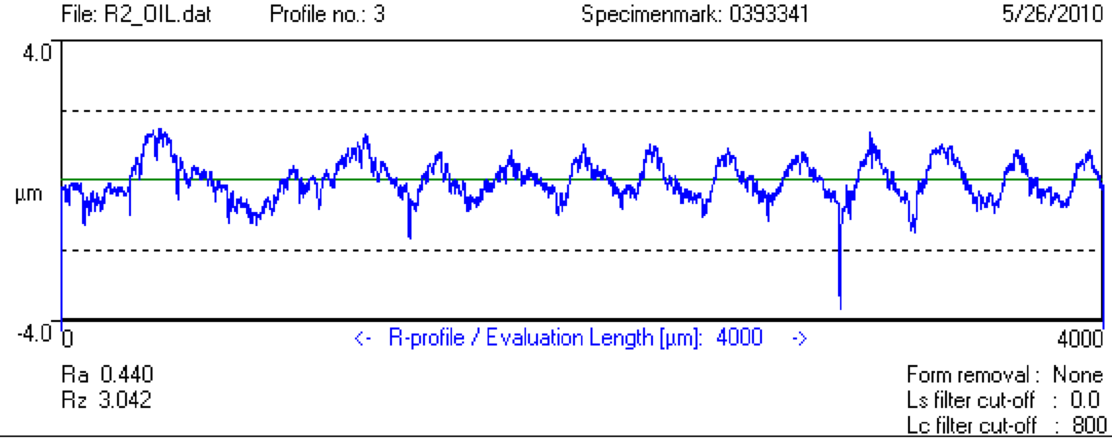
Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

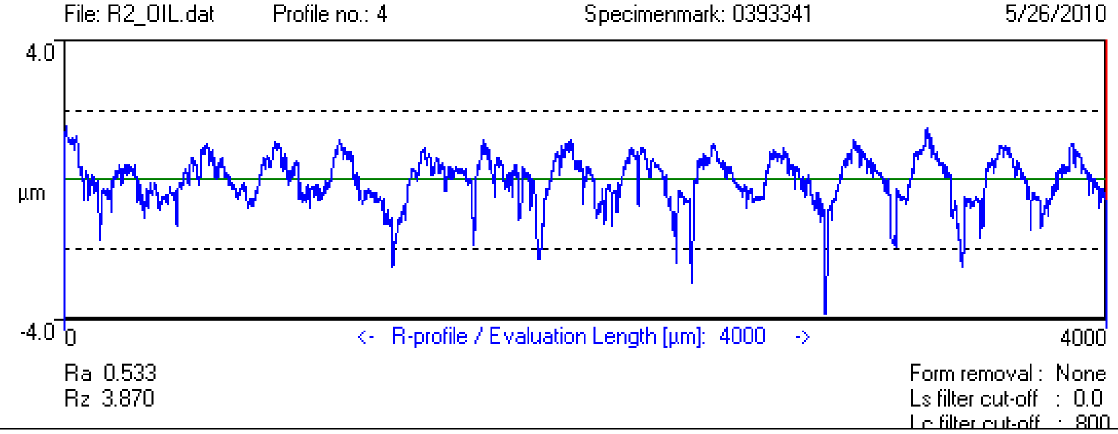
Operator C – 19/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R2 – OIL (R0.3/M)





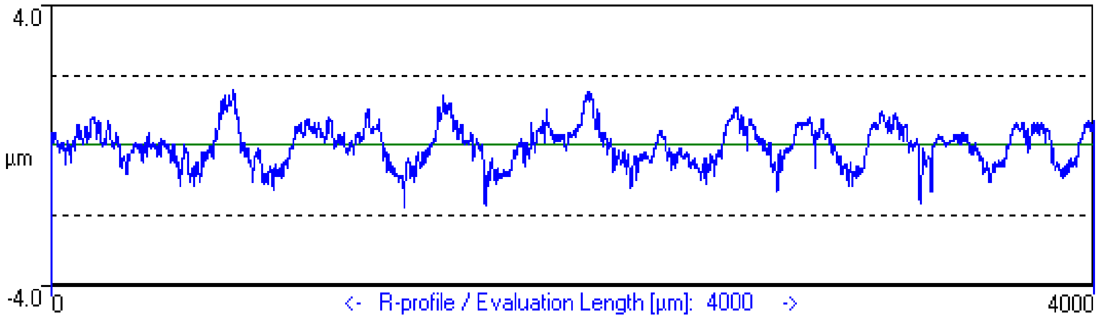




Operator C – 19/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R3 – OIL (R0.3/M)

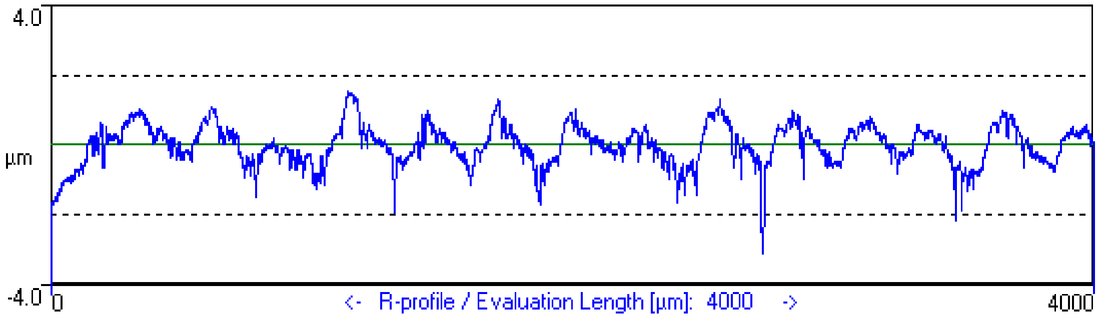
File: R3_OIL.dat   Profile no.: 1   Specimenmark: 0393341   5/26/2010



Ra 0.444
Rz 2.834

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

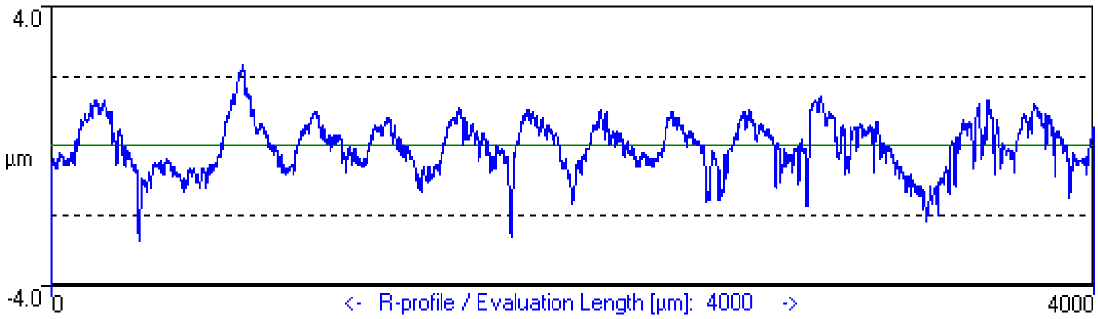
File: R3_OIL.dat   Profile no.: 2   Specimenmark: 0393341   5/26/2010



Ra 0.452
Rz 3.358

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

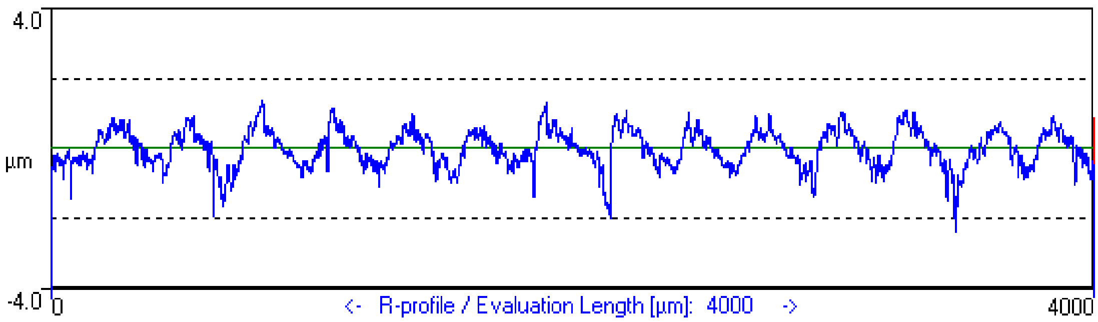
File: R3_OIL.dat   Profile no.: 3   Specimenmark: 0393341   5/26/2010



Ra 0.575
Rz 3.546

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

File: R3_OIL.dat   Profile no.: 4   Specimenmark: 0393341   5/26/2010



Ra 0.430
Rz 2.932

Form removal : None
Ls filter cut-off : 0.0
Lc filter cut-off : 800

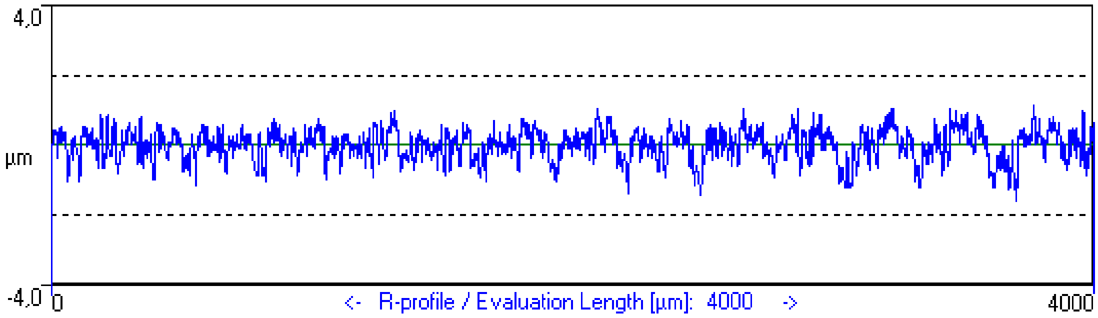
Appendix J4: Surface roughness measurement

Operator A: 26/04-2010

Operator A – 26/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P1 – 1% oil concentration (P0.3/W1)

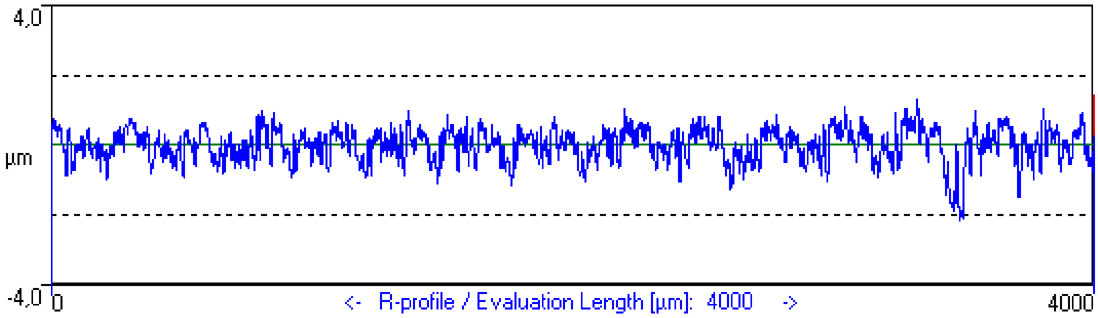
File: P1_1% Profile no.: 1 Specimenmark: 0393341 26-04-2010



Ra 0,354
Rz 2,332

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

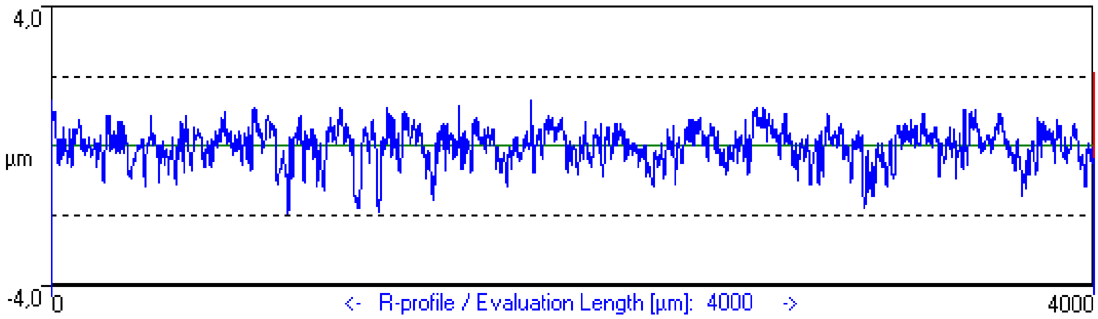
File: P1_1% Profile no.: 2 Specimenmark: 0393341 26-04-2010



Ra 0,371
Rz 2,386

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

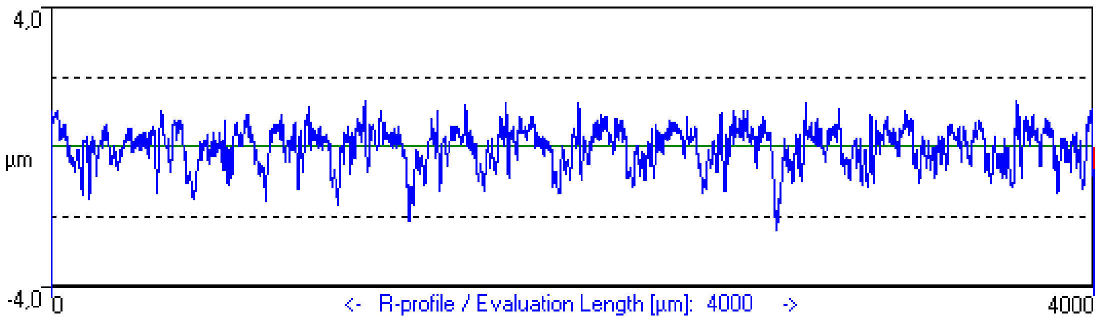
File: P1_1% Profile no.: 3 Specimenmark: 0393341 26-04-2010



Ra 0,392
Rz 2,666

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: P1_1% Profile no.: 4 Specimenmark: 0393341 26-04-2010



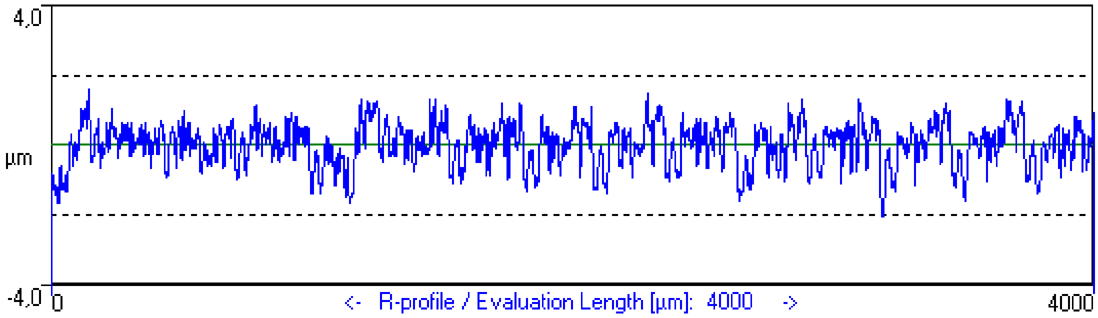
Ra 0,447
Rz 2,966

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator A – 26/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P2 – 1% oil concentration (P0.3/W1)

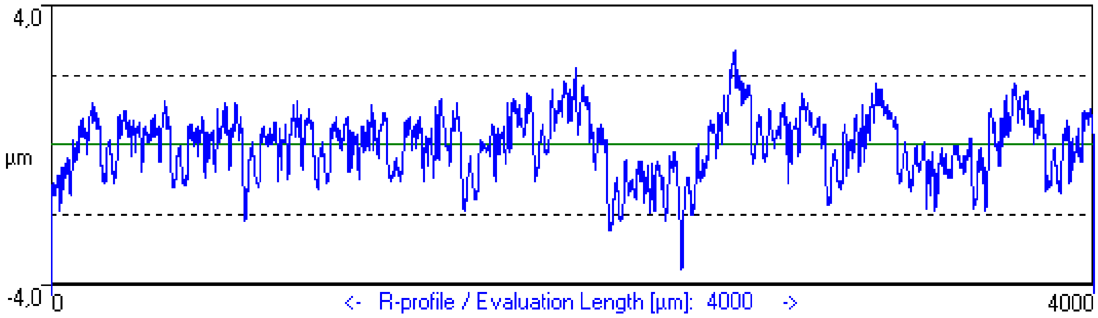
File: P2_1%   Profile no.: 1   Specimenmark: 0393341   26-04-2010



Ra 0,478
Rz 3,074

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

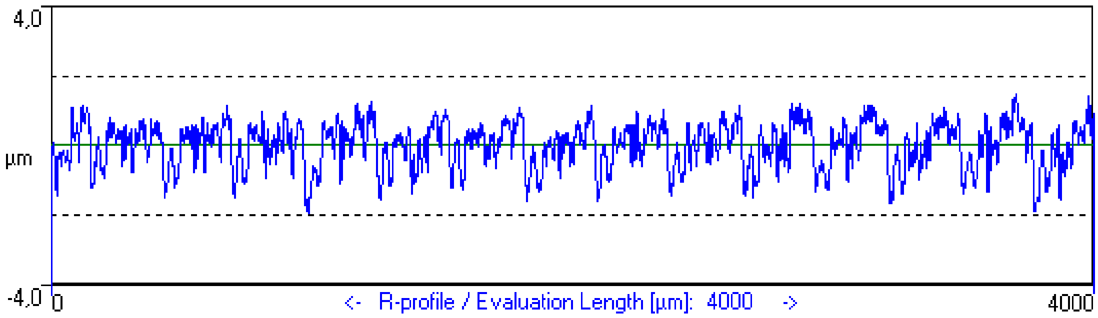
File: P2_1%   Profile no.: 2   Specimenmark: 0393341   26-04-2010



Ra 0,703
Rz 4,238

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

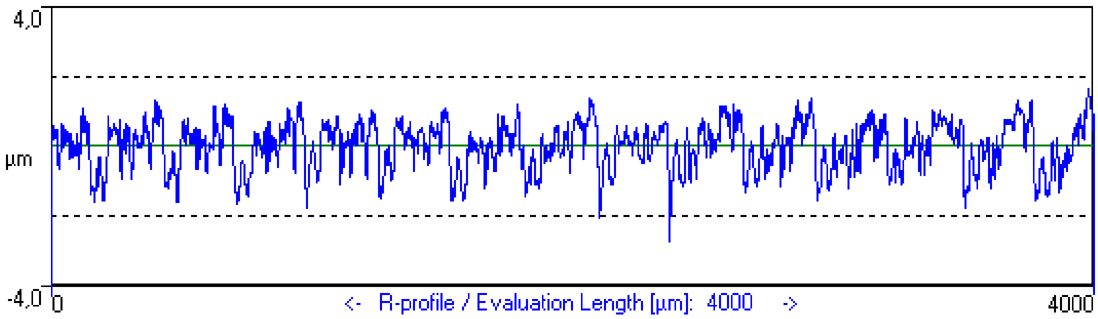
File: P2_1%   Profile no.: 3   Specimenmark: 0393341   26-04-2010



Ra 0,531
Rz 2,938

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: P2_1%   Profile no.: 4   Specimenmark: 0393341   26-04-2010

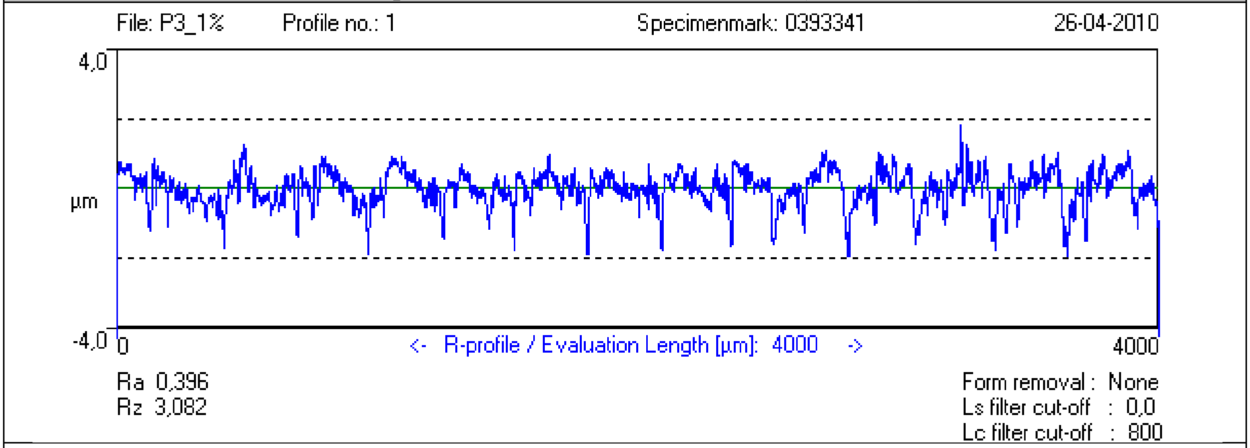


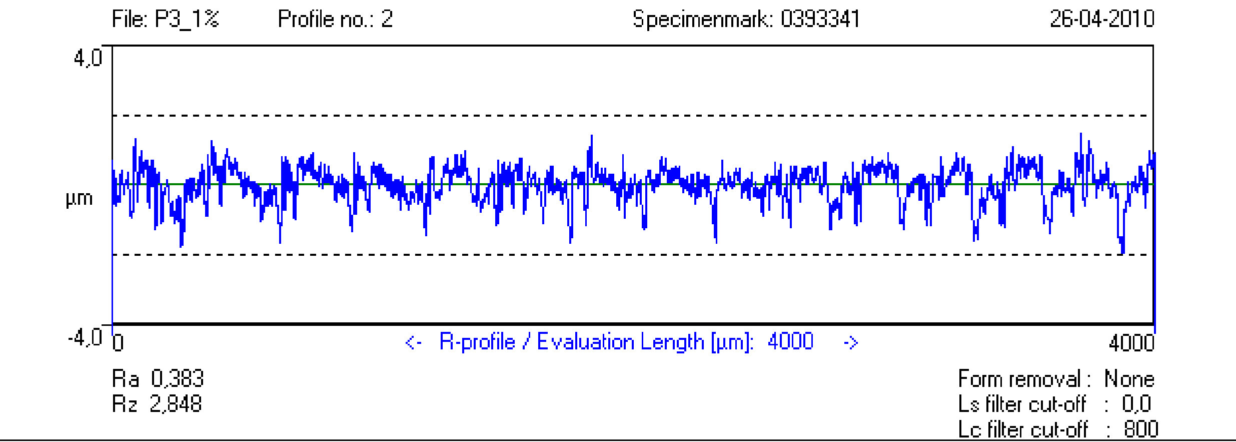
Ra 0,546
Rz 3,282

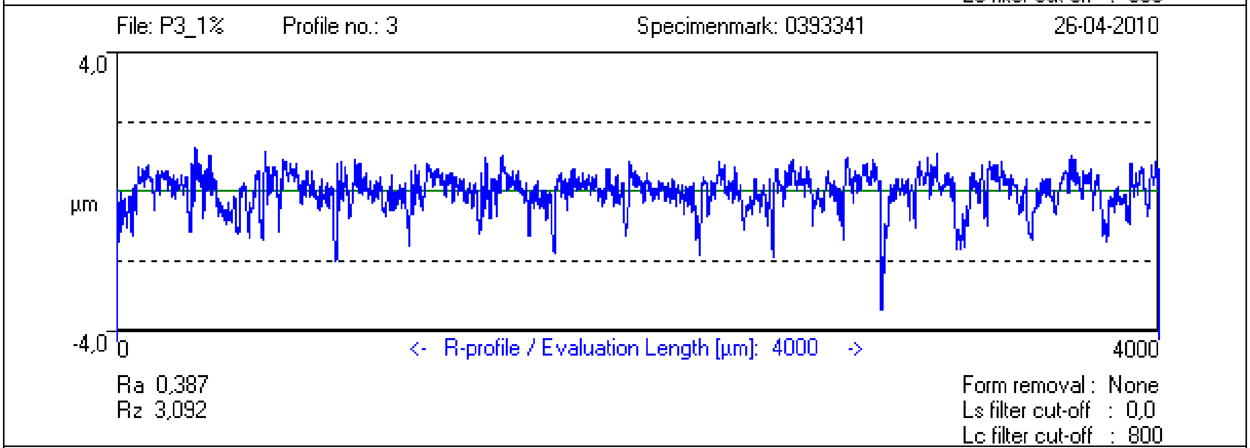
Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

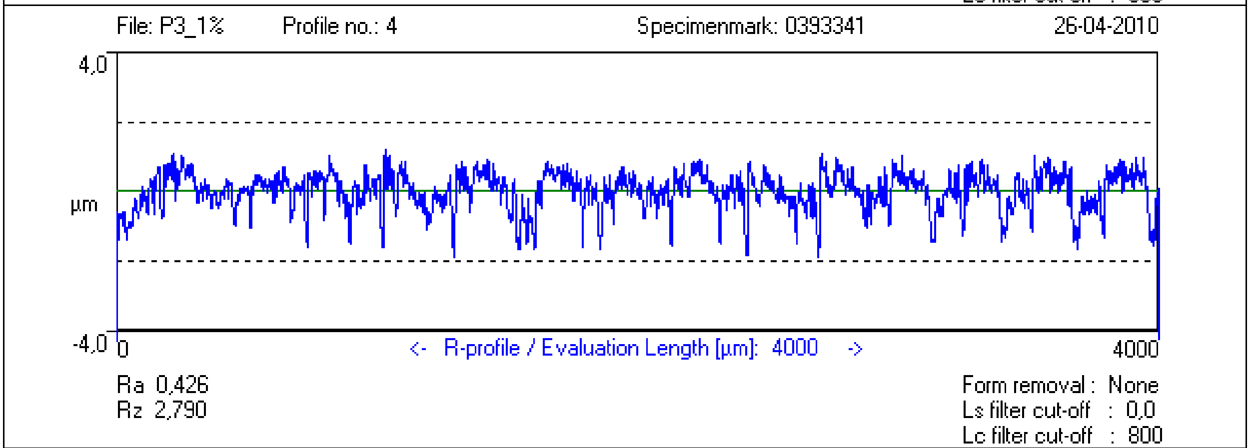
Operator A – 26/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P3 – 1% oil concentration (P0.3/W1)





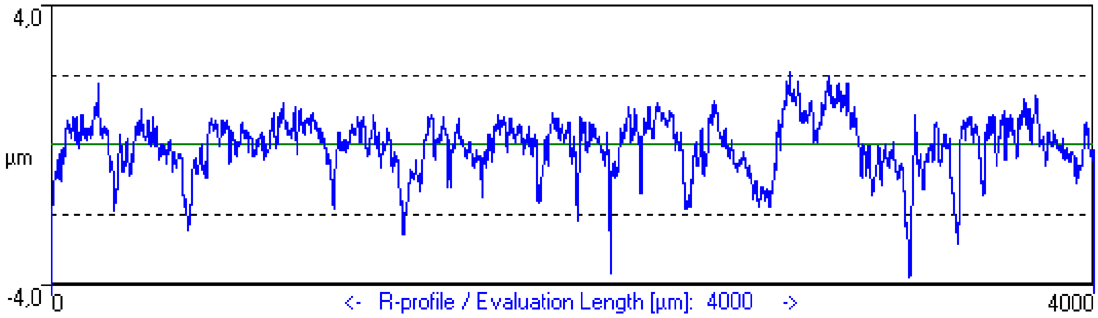




Operator A – 26/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R1 – 1% oil concentration (R0.3/W1)

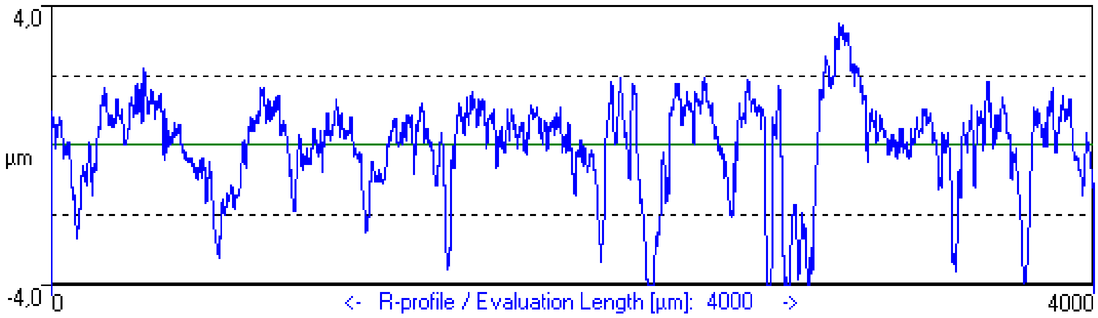
File: R1_1%   Profile no.: 1   Specimenmark: 0393341   26-04-2010



Ra 0,593
Rz 4,376

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

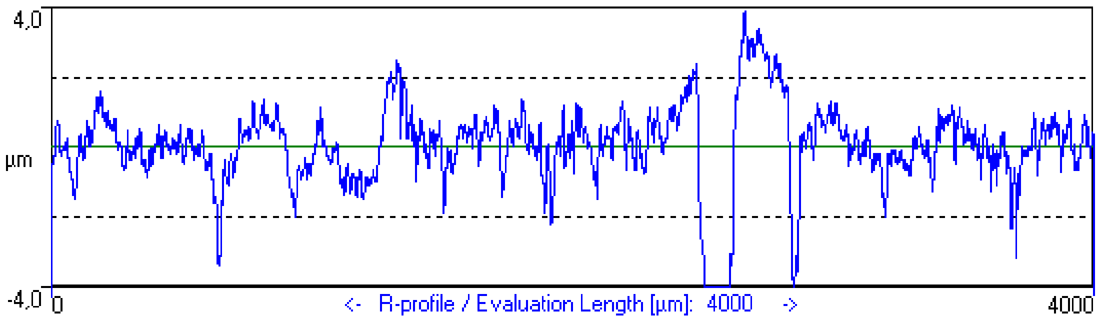
File: R1_1%   Profile no.: 2   Specimenmark: 0393341   26-04-2010



Ra 1,008
Rz 6,462

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

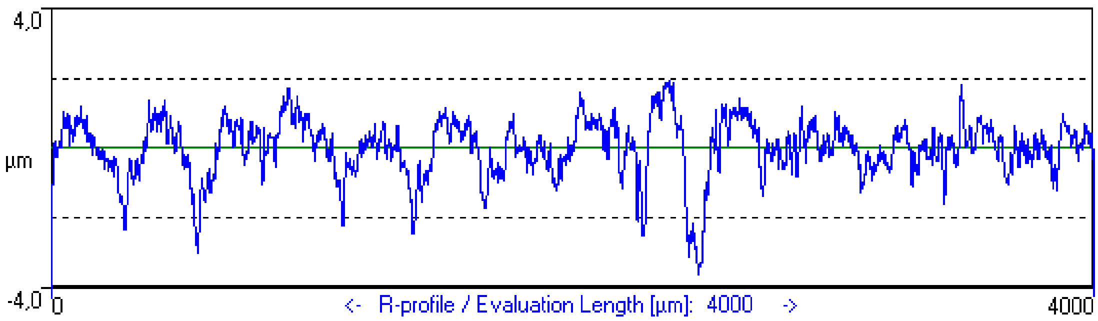
File: R1_1%   Profile no.: 3   Specimenmark: 0393341   26-04-2010



Ra 0,860
Rz 6,608

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: R1_1%   Profile no.: 4   Specimenmark: 0393341   26-04-2010



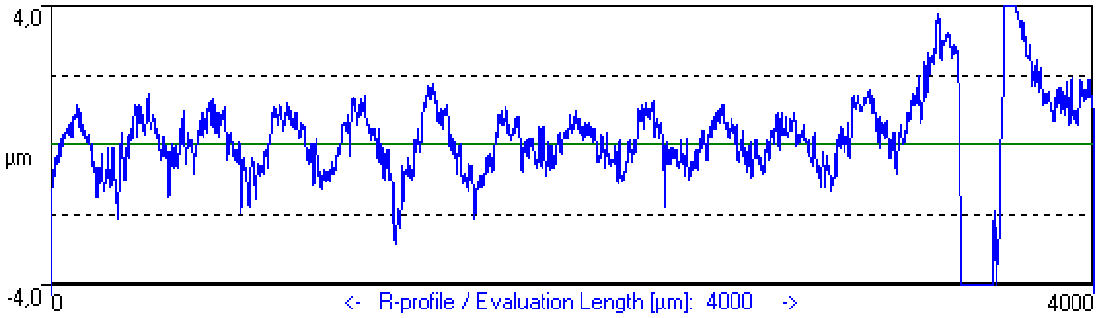
Ra 0,616
Rz 4,268

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator A – 26/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R2 – 1% oil concentration (R0.3/W1)

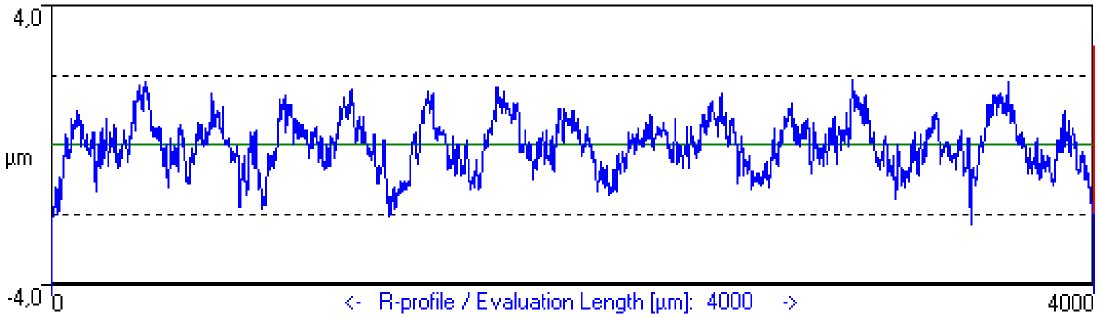
File: R2_1%   Profile no.: 1   Specimenmark: 0393341   26-04-2010



Ra 1,096
Rz 7,130

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

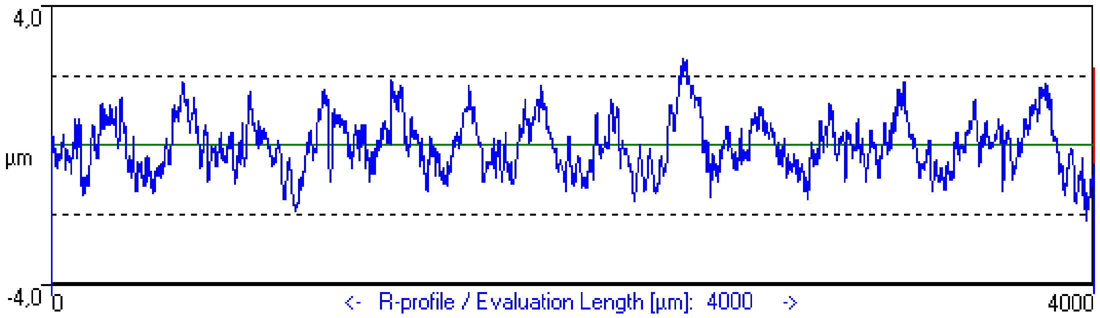
File: R2_1%   Profile no.: 2   Specimenmark: 0393341   26-04-2010



Ra 0,577
Rz 3,664

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

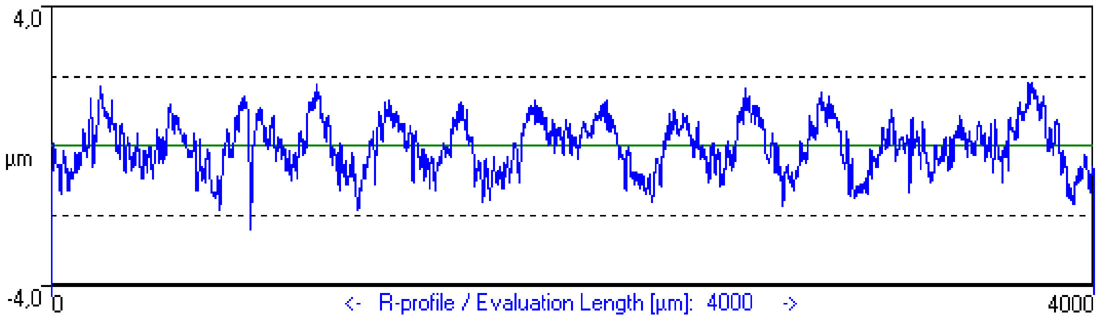
File: R2_1%   Profile no.: 3   Specimenmark: 0393341   26-04-2010



Ra 0,619
Rz 3,664

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: R2_1%   Profile no.: 4   Specimenmark: 0393341   26-04-2010



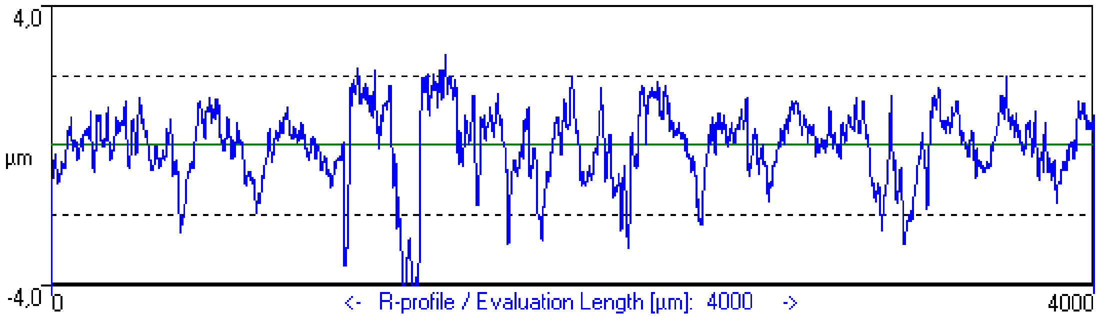
Ra 0,599
Rz 3,470

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator A – 26/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R3 – 1% oil concentration (R0.3/W1)

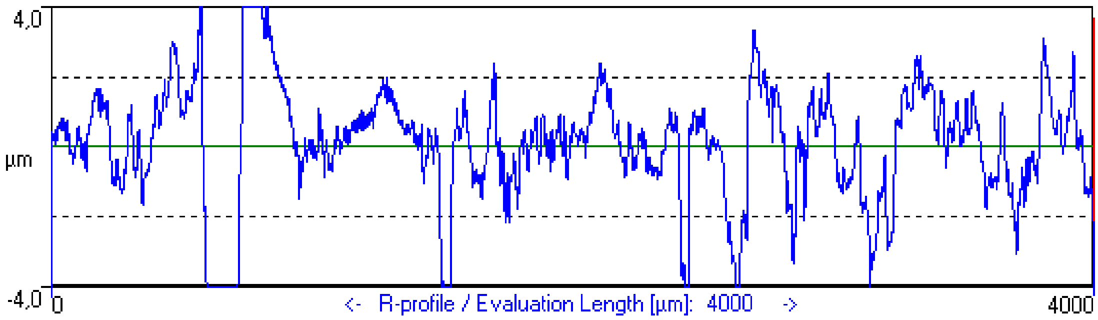
File: R3_1% Profile no.: 1 Specimenmark: 0393341 26-04-2010



Ra 0,810
Rz 4,938

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

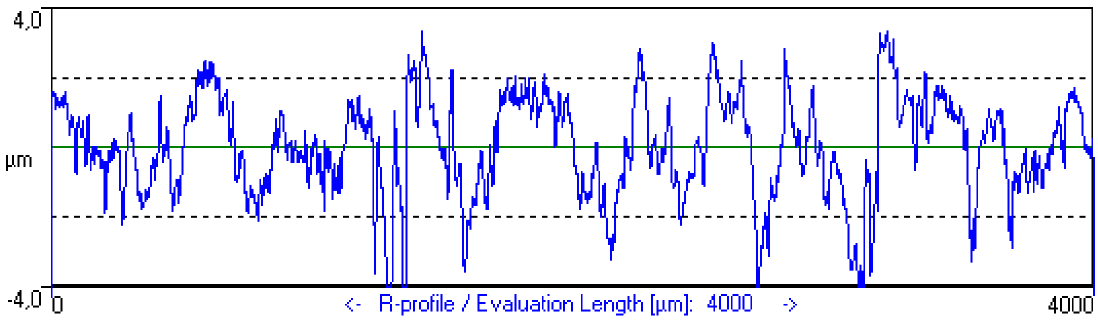
File: R3_1% Profile no.: 2 Specimenmark: 0393341 26-04-2010



Ra 1,363
Rz 9,458

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

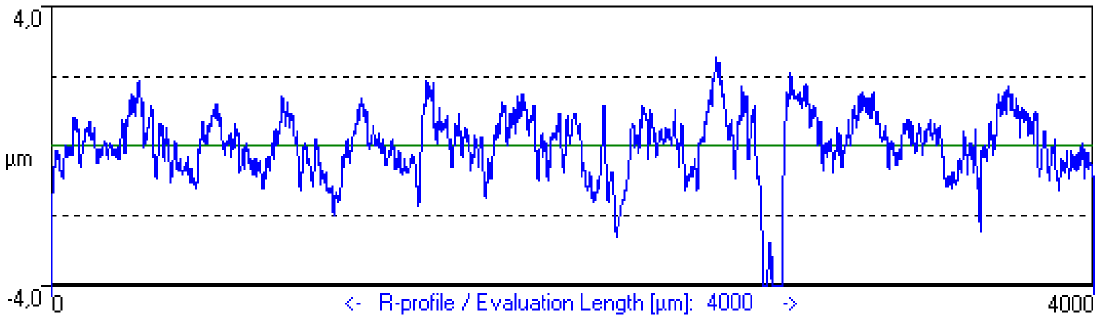
File: R3_1% Profile no.: 3 Specimenmark: 0393341 26-04-2010



Ra 1,153
Rz 7,310

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: R3_1% Profile no.: 4 Specimenmark: 0393341 26-04-2010



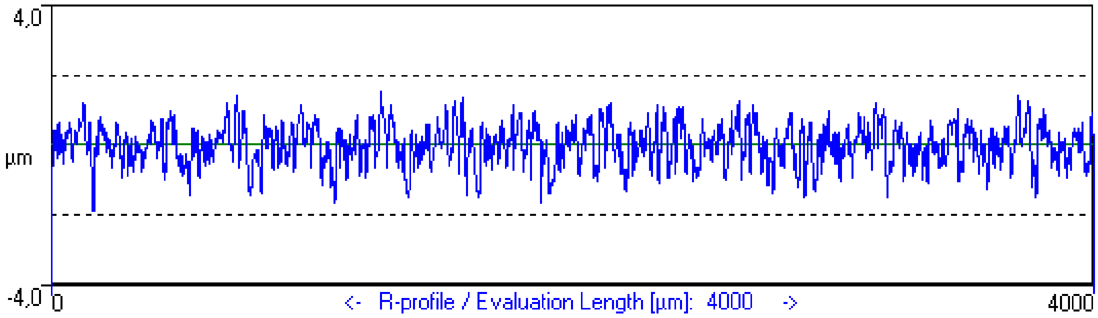
Ra 0,713
Rz 4,762

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator A – 26/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P1 – 10% oil concentration (P0.3/W2)

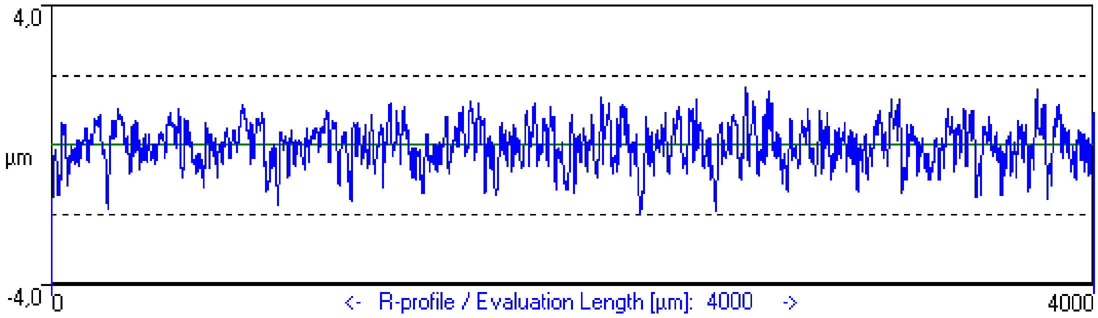
File: P1_10%   Profile no.: 1   Specimenmark: 0393341   26-04-2010



Ra 0,450
Rz 2,998

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

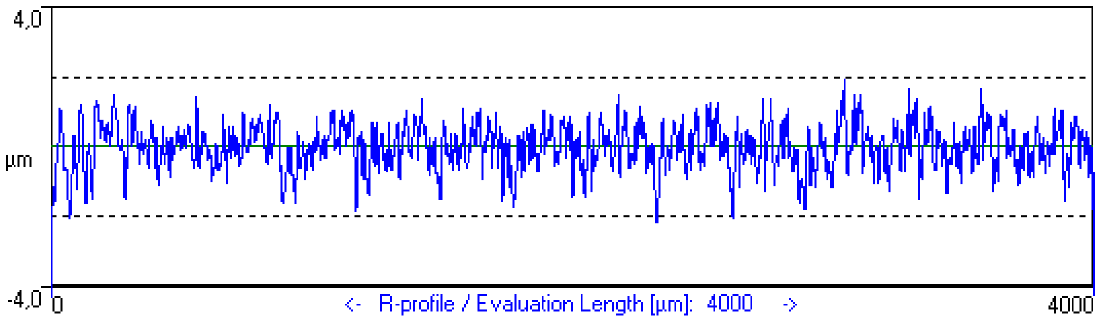
File: P1_10%   Profile no.: 2   Specimenmark: 0393341   26-04-2010



Ra 0,470
Rz 3,250

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

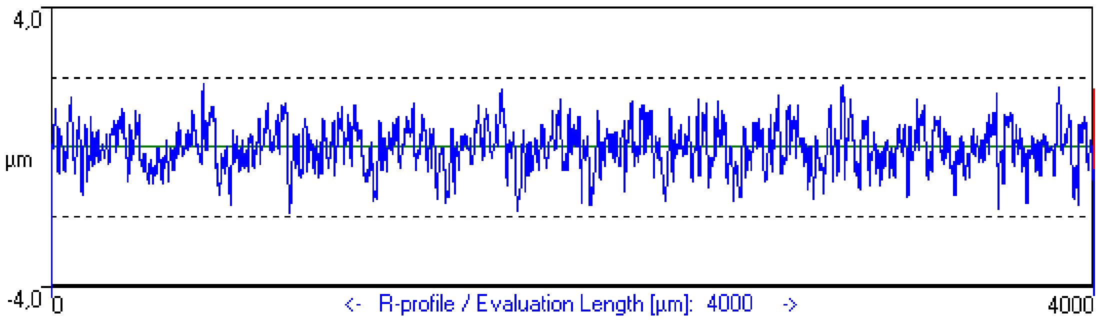
File: P1_10%   Profile no.: 3   Specimenmark: 0393341   26-04-2010



Ra 0,501
Rz 3,532

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: P1_10%   Profile no.: 4   Specimenmark: 0393341   26-04-2010

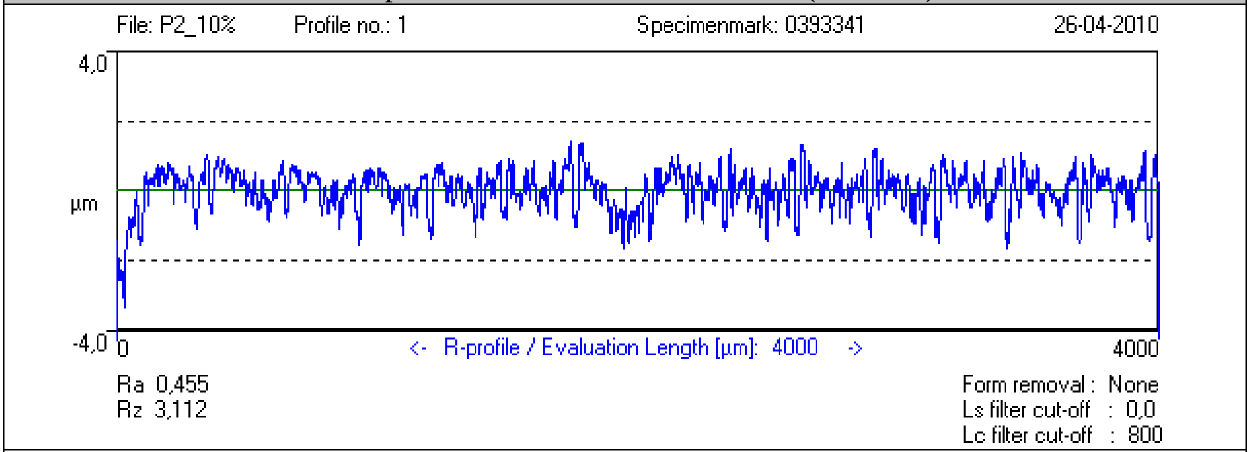


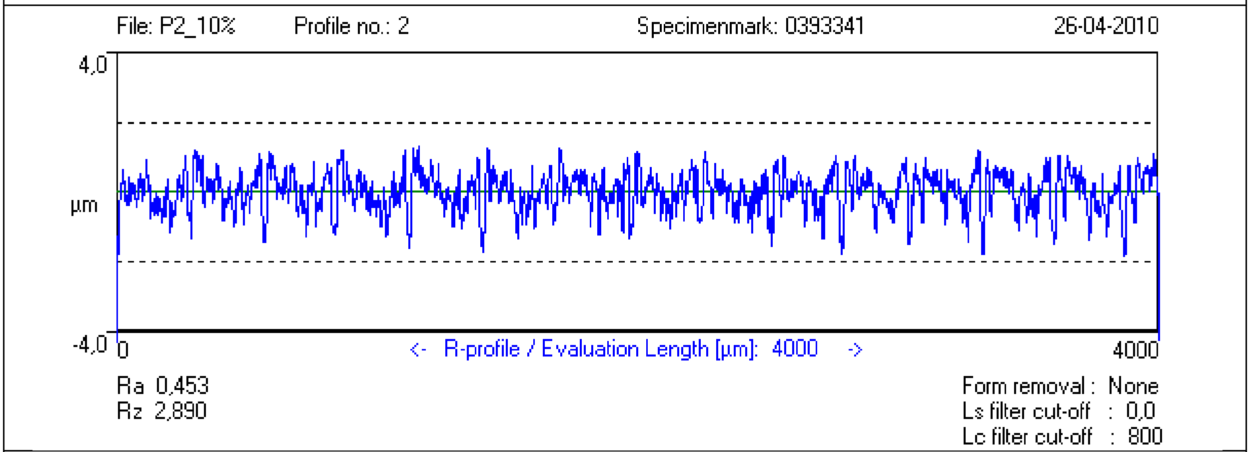
Ra 0,483
Rz 3,364

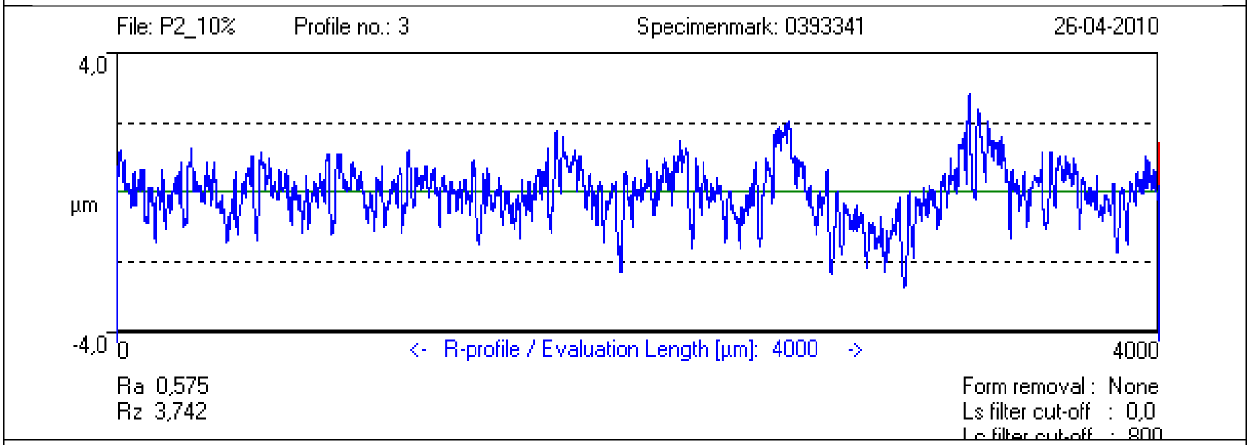
Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

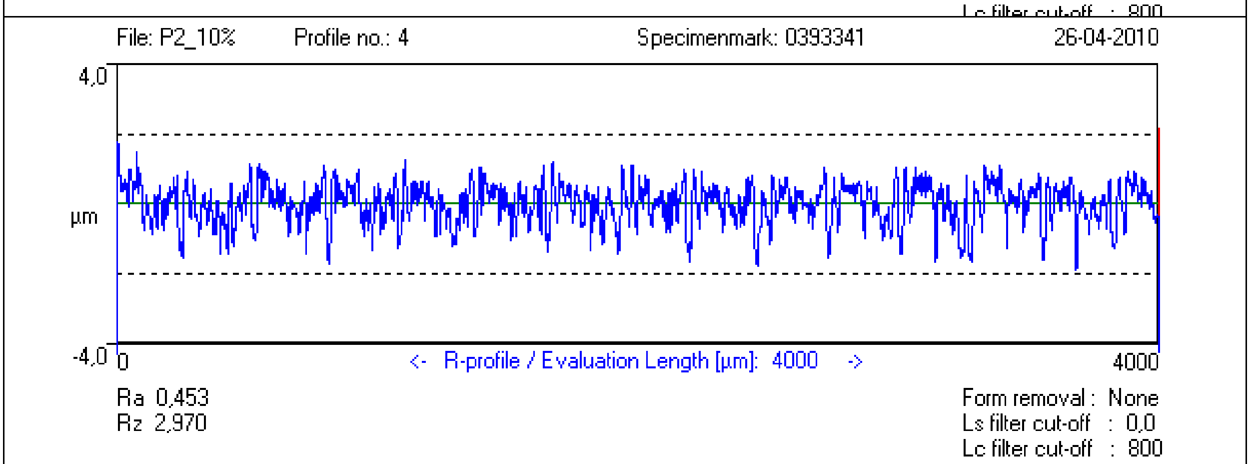
Operator A – 26/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P2 – 10% oil concentration (P0.3/W2)



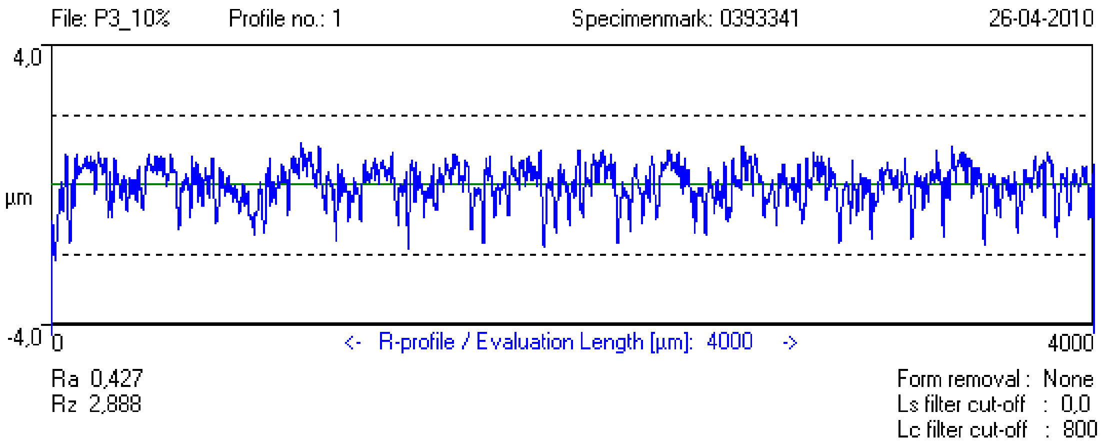


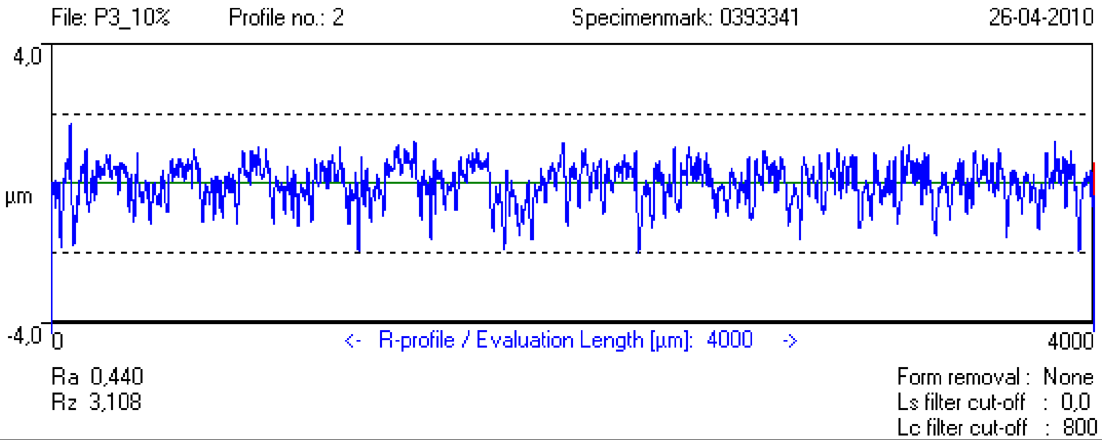


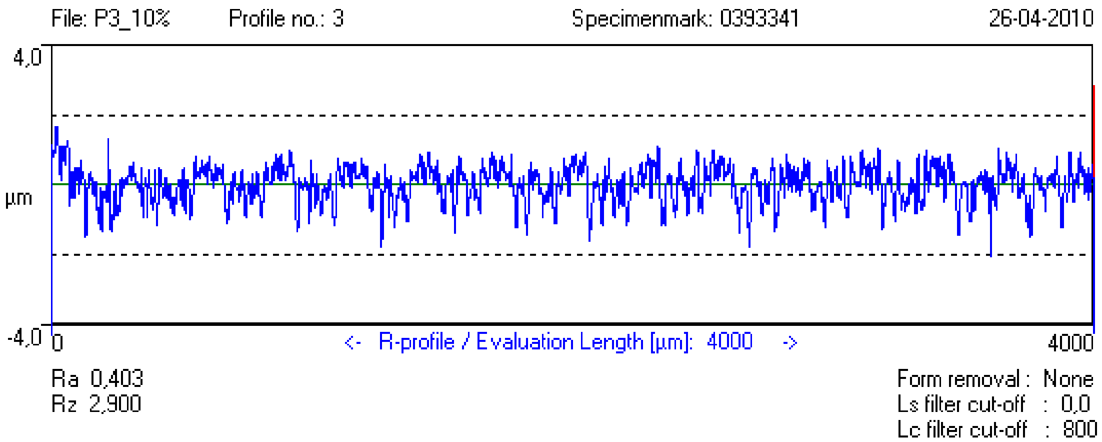


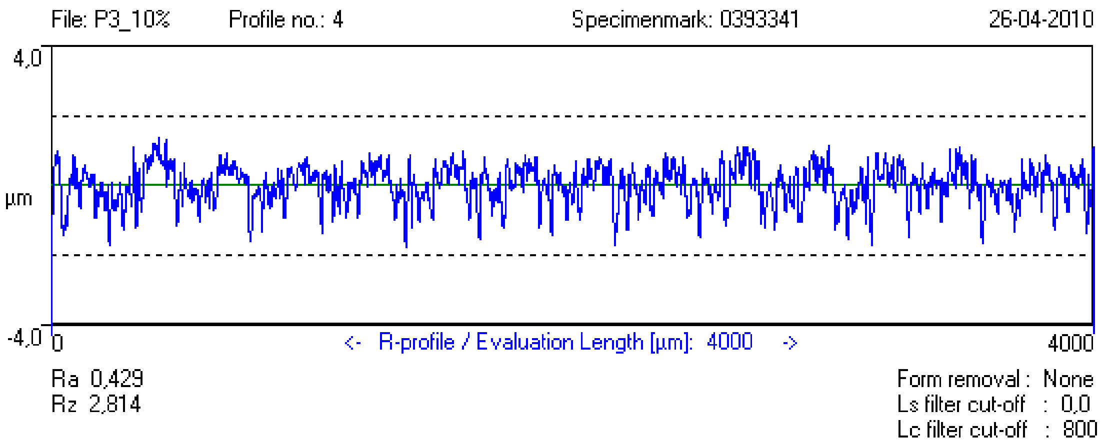
Operator A – 26/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P3 – 10% oil concentration (P0.3/W2)





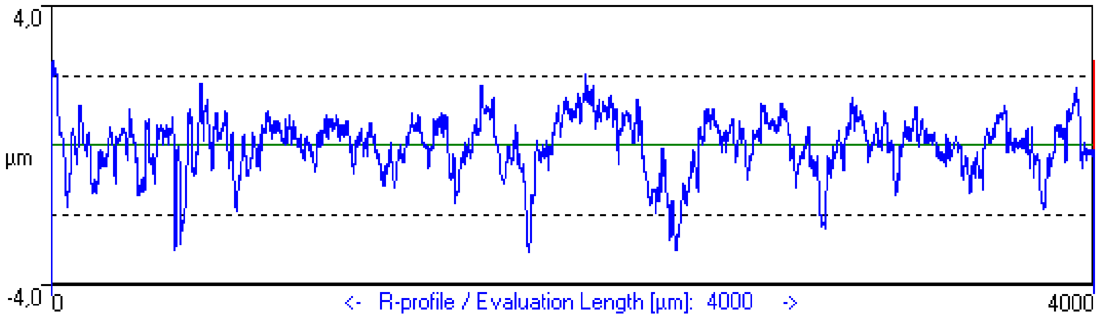




Operator A – 26/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R1 – 10% oil concentration (R0.3/W2)

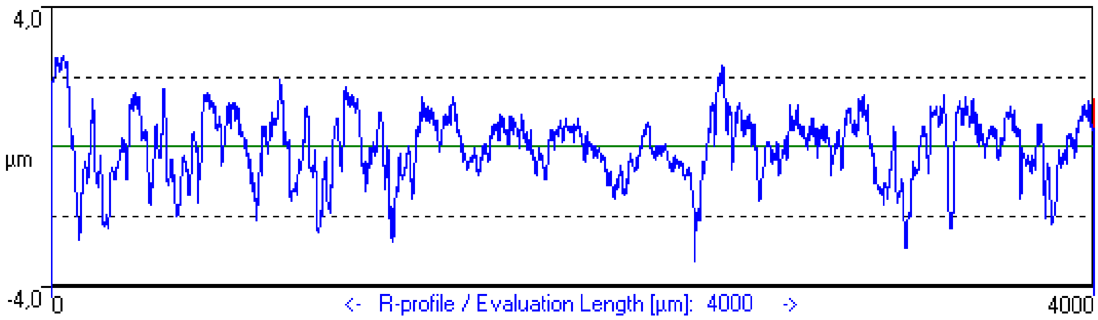
File: R1_10% Profile no.: 1 Specimenmark: 0393341 26-04-2010



Ra 0,624
Rz 4,136

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

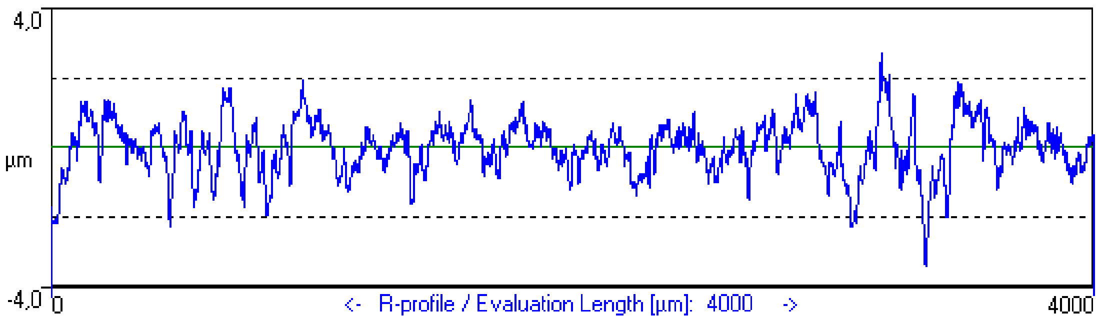
File: R1_10% Profile no.: 2 Specimenmark: 0393341 26-04-2010



Ra 0,740
Rz 4,446

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

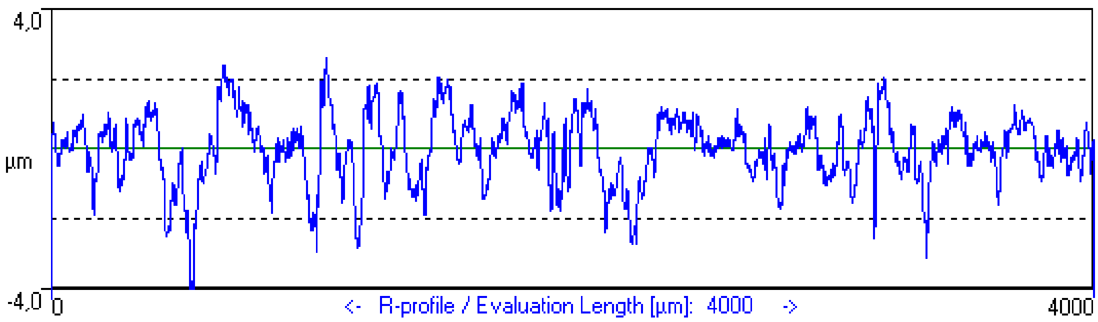
File: R1_10% Profile no.: 3 Specimenmark: 0393341 26-04-2010



Ra 0,601
Rz 4,220

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: R1_10% Profile no.: 4 Specimenmark: 0393341 26-04-2010

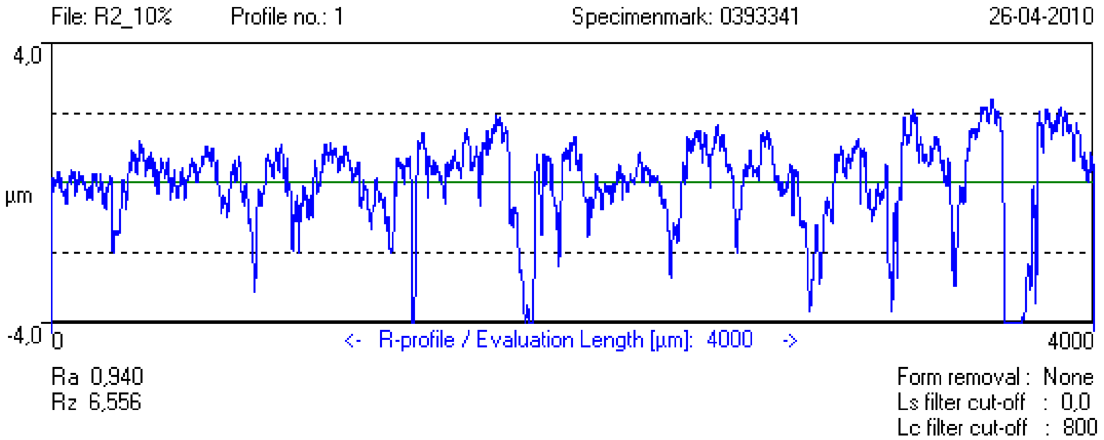


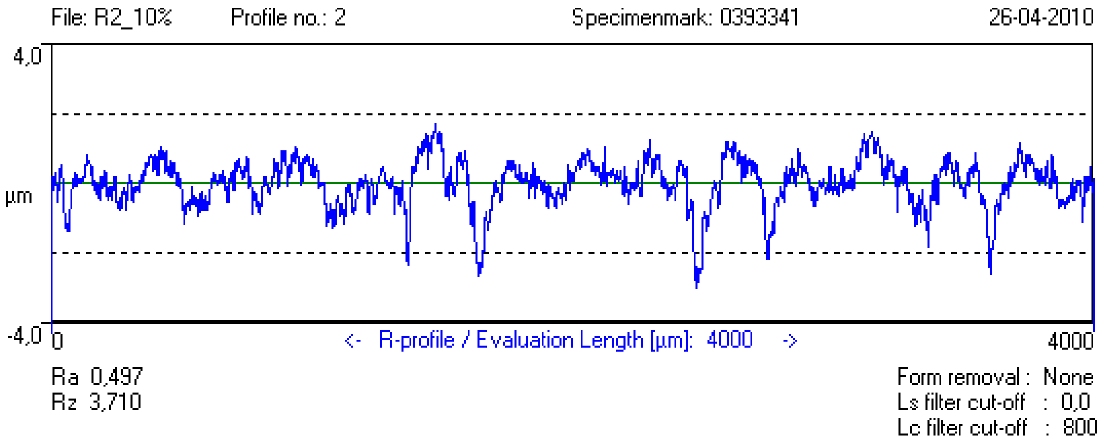
Ra 0,753
Rz 5,324

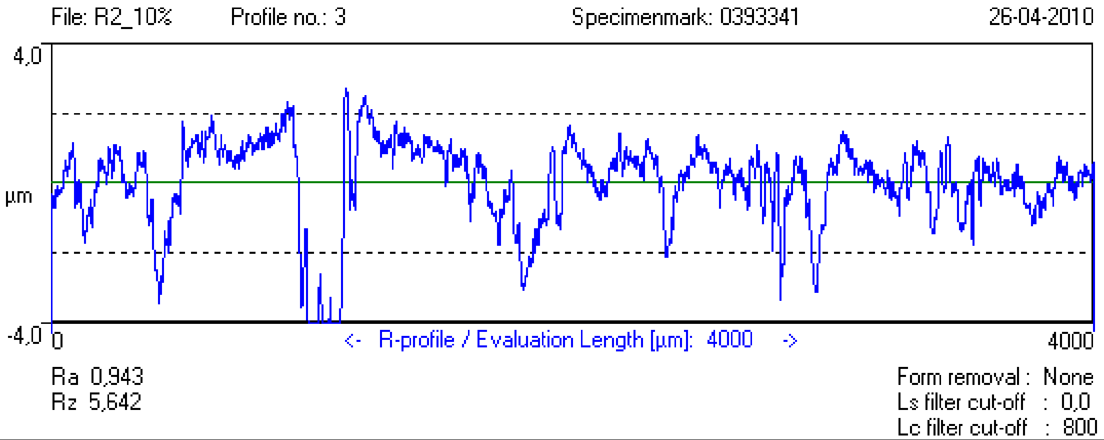
Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

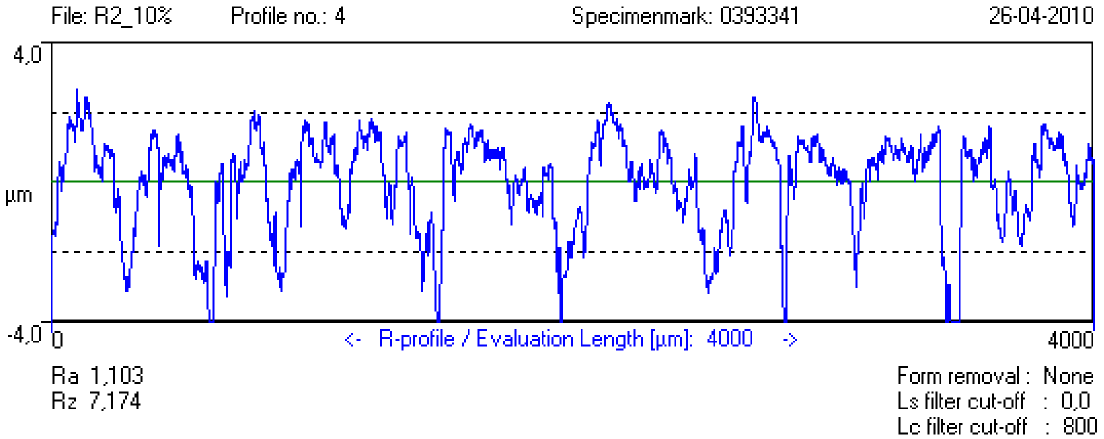
Operator A – 26/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R2 – 10% oil concentration (R0.3/W2)





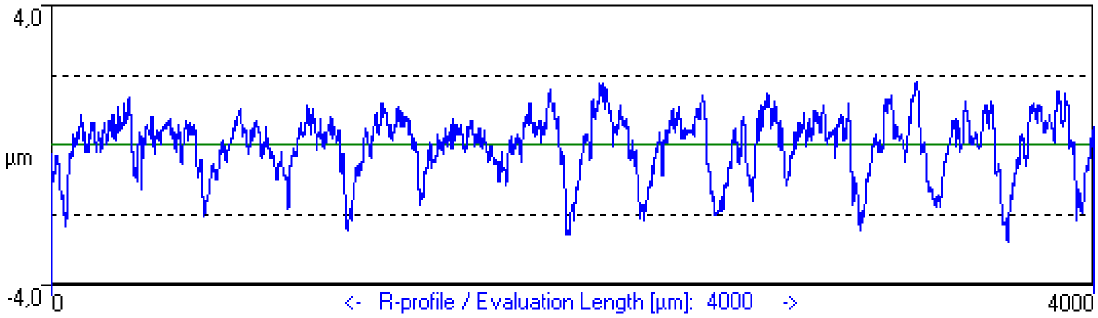




Operator A – 26/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R3 – 10% oil concentration (R0.3/W2)

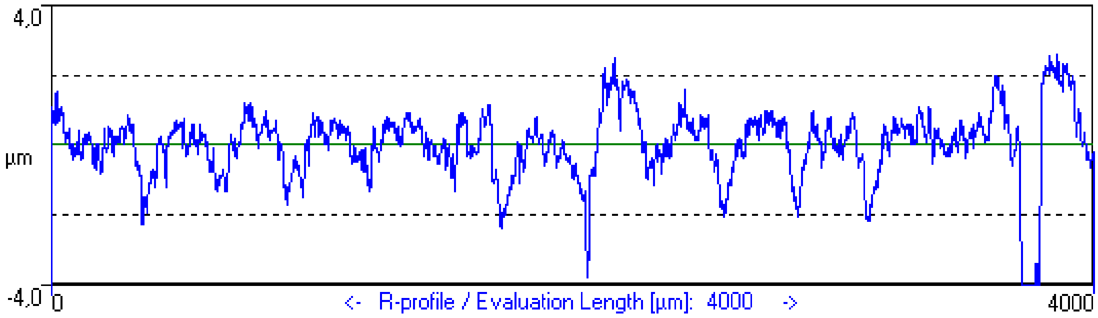
File: R3_10% Profile no.: 1 Specimenmark: 0393341 26-04-2010



Ra 0,666
Rz 4,036

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

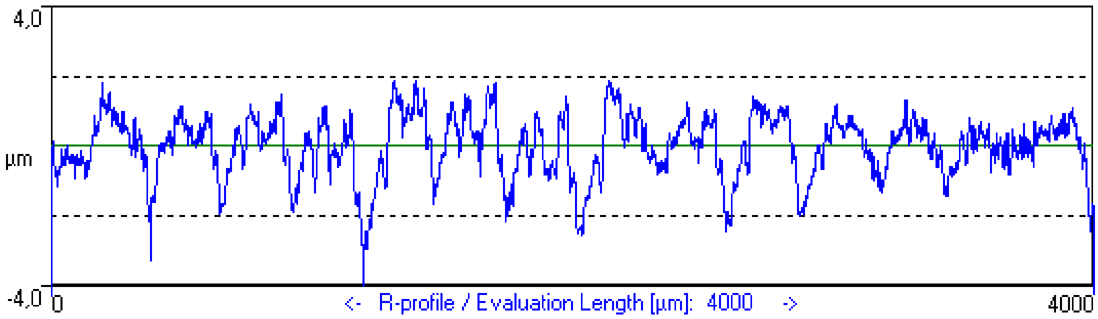
File: R3_10% Profile no.: 2 Specimenmark: 0393341 26-04-2010



Ra 0,723
Rz 5,220

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

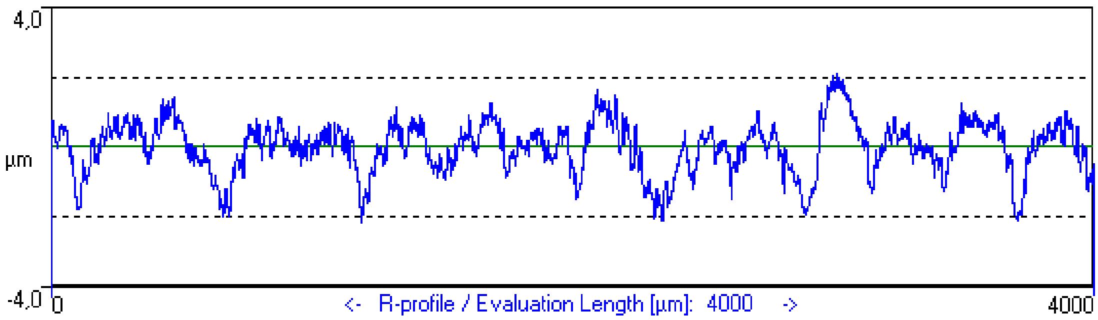
File: R3_10% Profile no.: 3 Specimenmark: 0393341 26-04-2010



Ra 0,696
Rz 4,608

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: R3_10% Profile no.: 4 Specimenmark: 0393341 26-04-2010



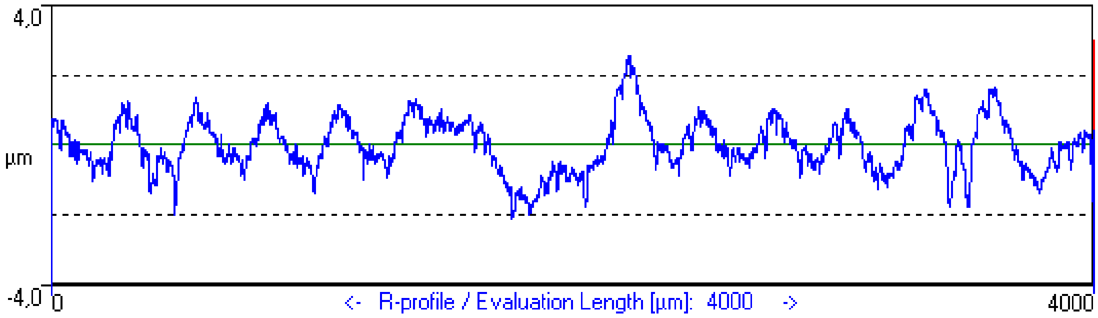
Ra 0,579
Rz 3,560

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator A – 26/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P1 – OIL (P0.3/M)

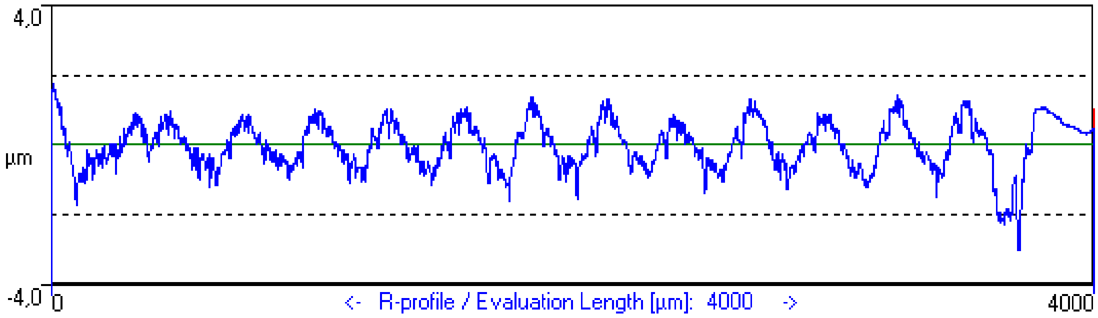
File: P1_100% Profile no.: 1 Specimenmark: 0393341 26-04-2010



Ra 0,620
Rz 3,292

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

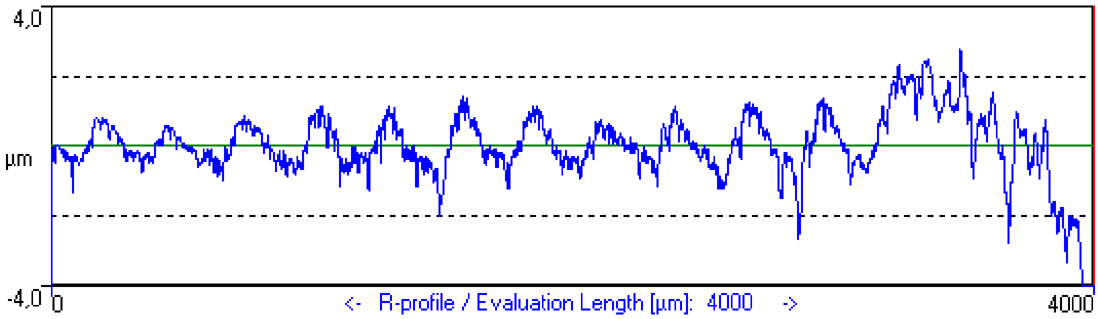
File: P1_100% Profile no.: 2 Specimenmark: 0393341 26-04-2010



Ra 0,559
Rz 3,146

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

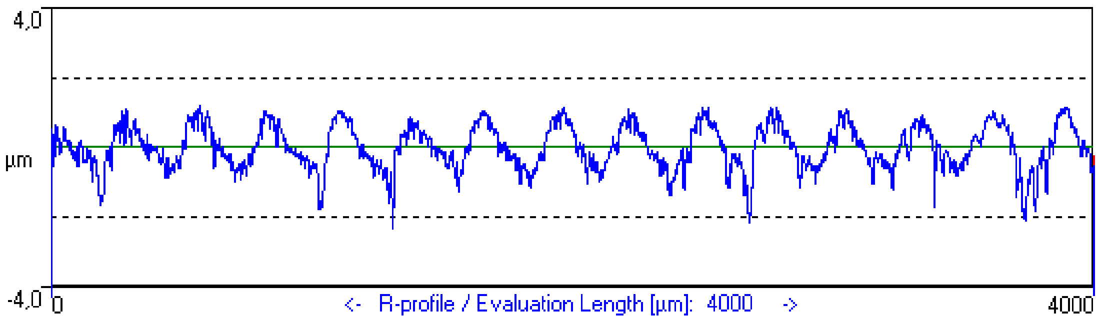
File: P1_100% Profile no.: 3 Specimenmark: 0393341 26-04-2010



Ra 0,687
Rz 4,288

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: P1_100% Profile no.: 4 Specimenmark: 0393341 26-04-2010



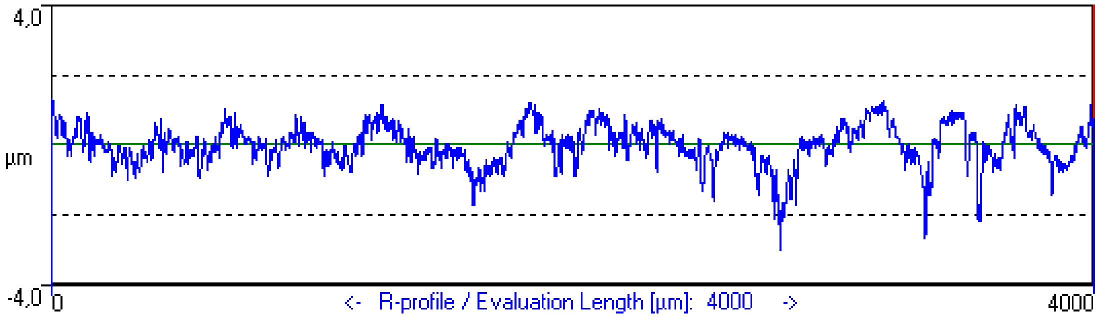
Ra 0,517
Rz 3,054

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator A – 26/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P2 – OIL (P0.3/M)

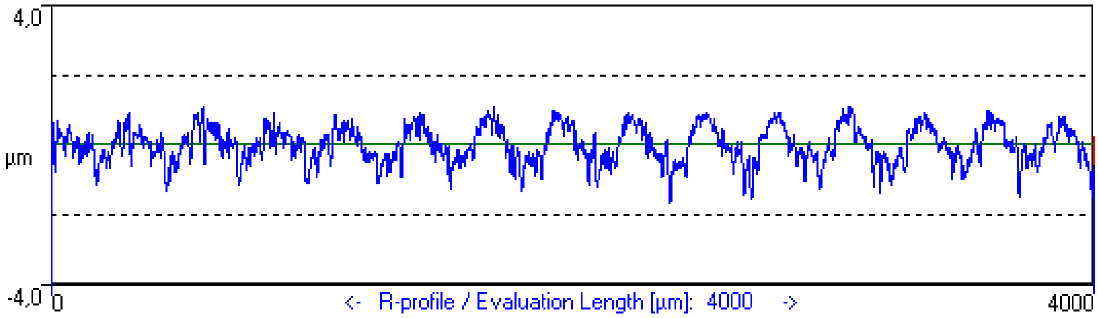
File: P2_100%   Profile no.: 1   Specimenmark: 0393341   26-04-2010



Ra 0,438
Rz 3,068

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

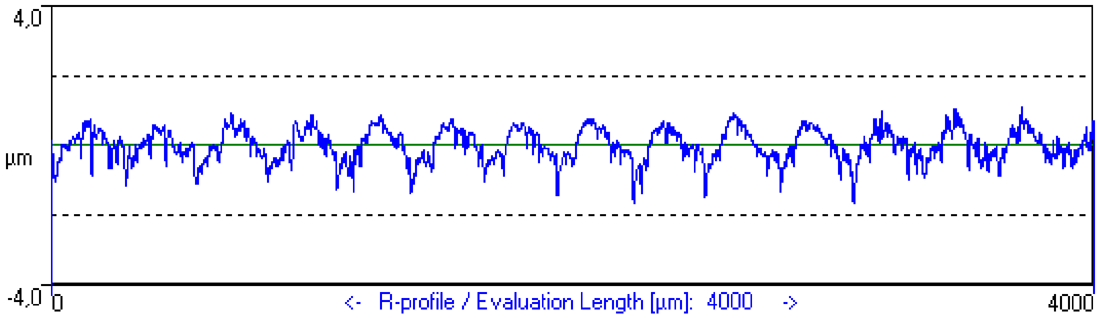
File: P2_100%   Profile no.: 2   Specimenmark: 0393341   26-04-2010



Ra 0,428
Rz 2,494

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

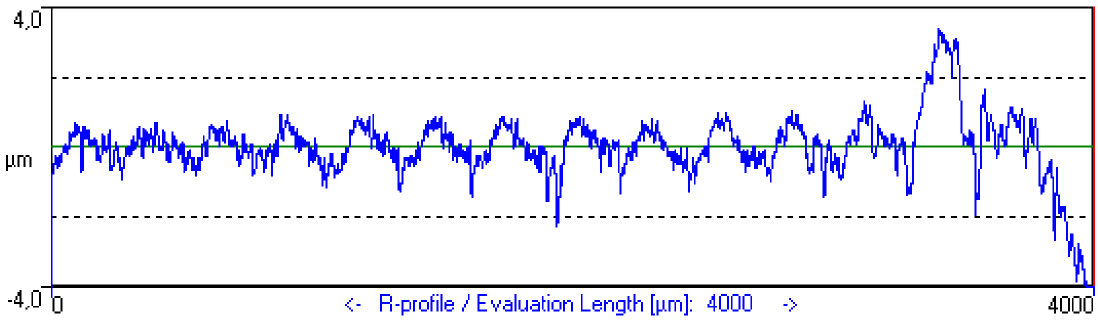
File: P2_100%   Profile no.: 3   Specimenmark: 0393341   26-04-2010



Ra 0,374
Rz 2,286

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: P2_100%   Profile no.: 4   Specimenmark: 0393341   26-04-2010



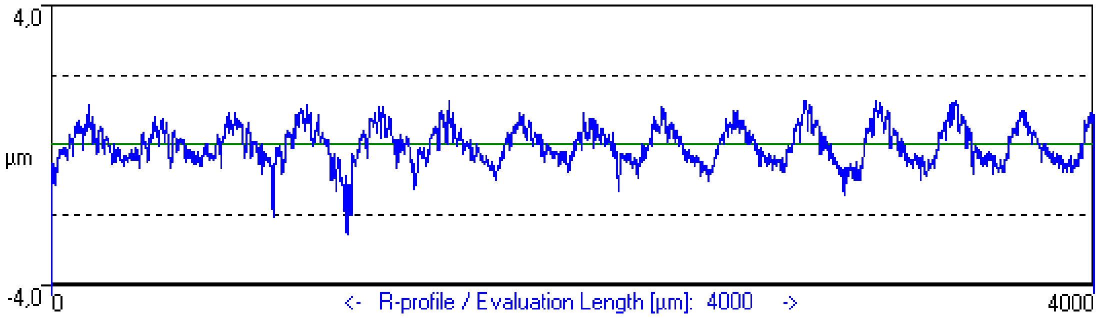
Ra 0,599
Rz 3,766

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator A – 26/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P3 – OIL (P0.3/M)

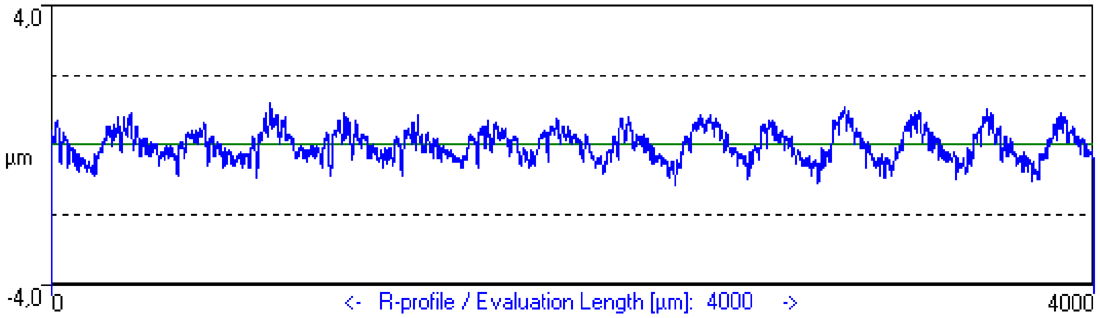
File: P3_100%   Profile no.: 1   Specimenmark: 0393341   26-04-2010



Ra 0,432
Rz 2,678

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

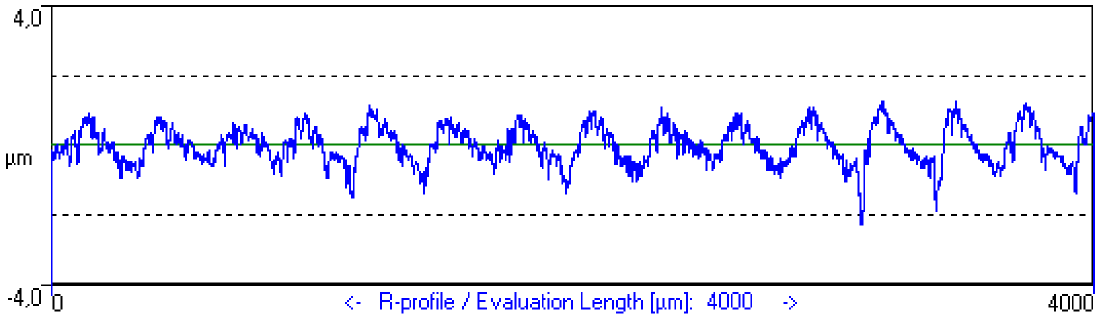
File: P3_100%   Profile no.: 2   Specimenmark: 0393341   26-04-2010



Ra 0,350
Rz 2,014

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

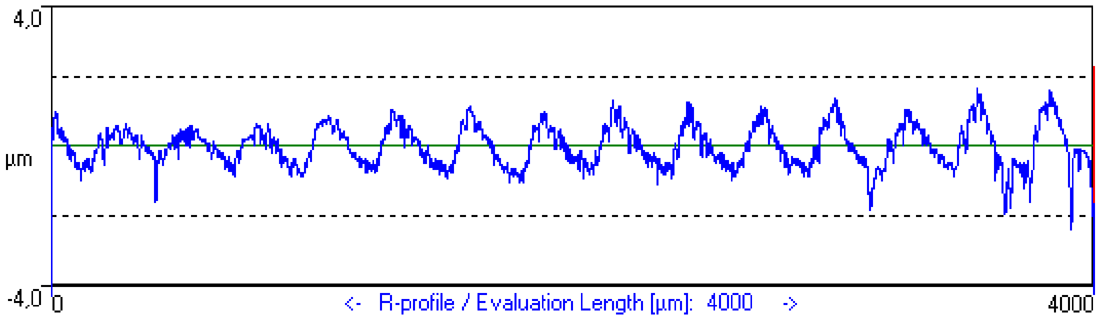
File: P3_100%   Profile no.: 3   Specimenmark: 0393341   26-04-2010



Ra 0,435
Rz 2,730

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: P3_100%   Profile no.: 4   Specimenmark: 0393341   26-04-2010



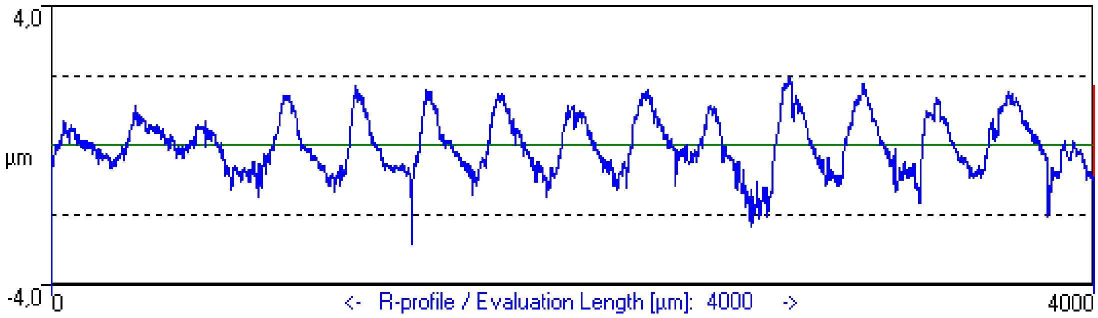
Ra 0,486
Rz 2,826

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator A – 26/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R1 – OIL (R0.3/M)

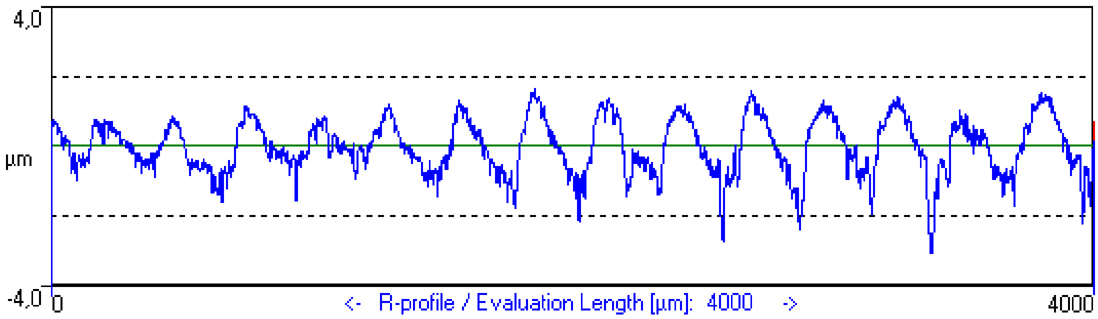
File: R1_100% Profile no.: 1 Specimenmark: 0393341 26-04-2010



Ra 0,644
Rz 3,614

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

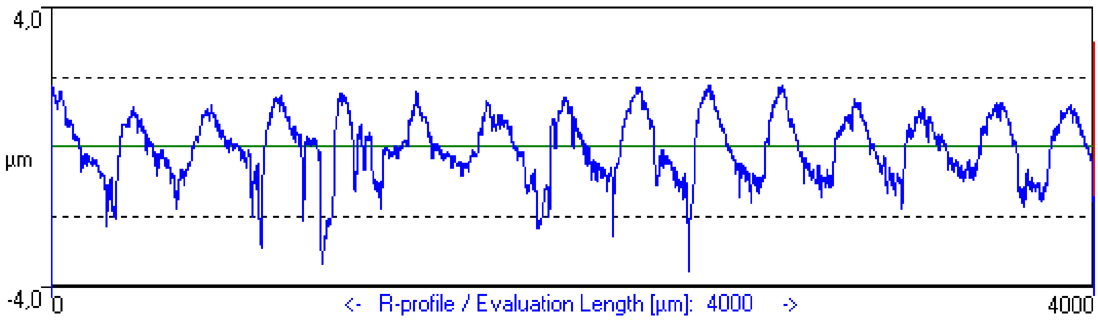
File: R1_100% Profile no.: 2 Specimenmark: 0393341 26-04-2010



Ra 0,642
Rz 3,658

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

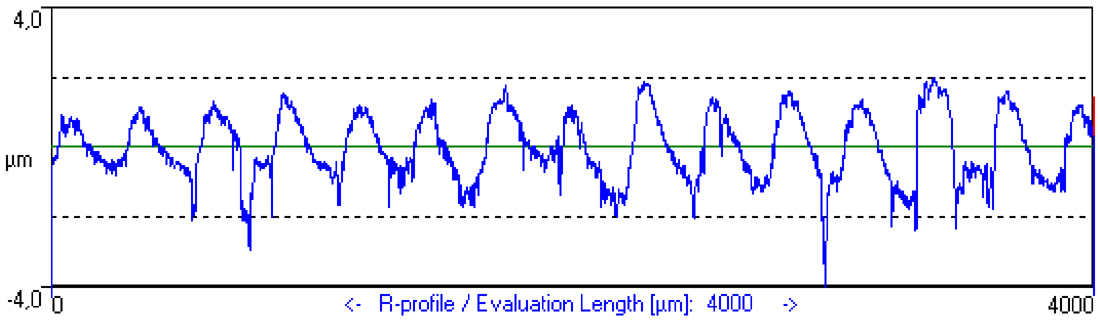
File: R1_100% Profile no.: 3 Specimenmark: 0393341 26-04-2010



Ra 0,743
Rz 4,370

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: R1_100% Profile no.: 4 Specimenmark: 0393341 26-04-2010



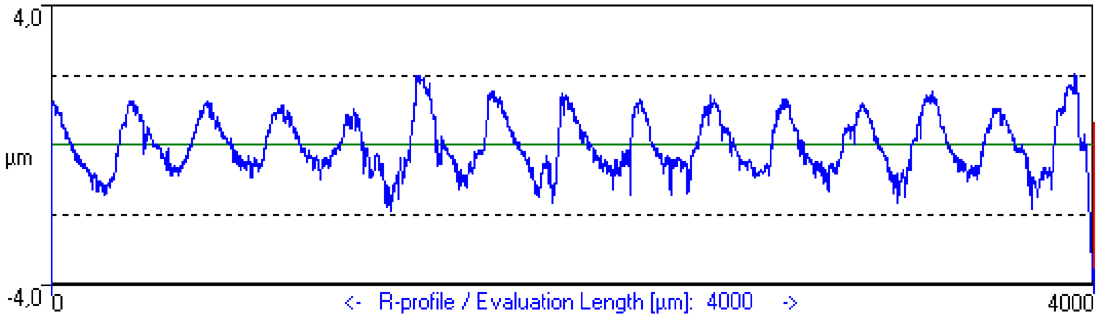
Ra 0,799
Rz 4,434

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator A – 26/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R2 – OIL (R0.3/M)

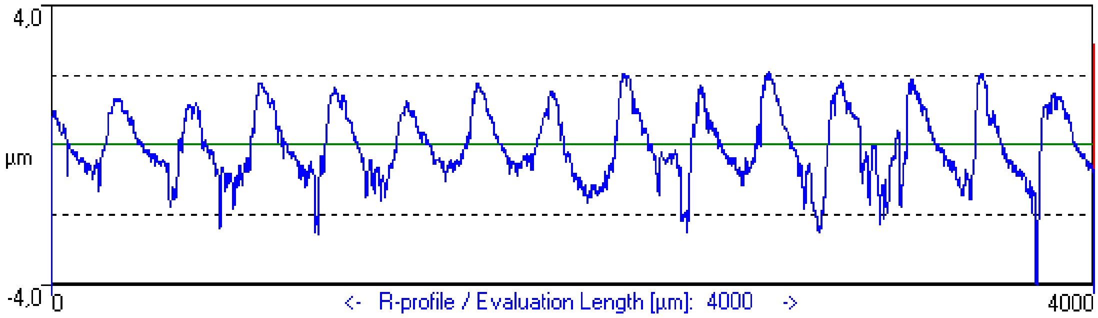
File: R2_100%   Profile no.: 1   Specimenmark: 0393341   26-04-2010



Ra 0,667
Rz 3,660

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

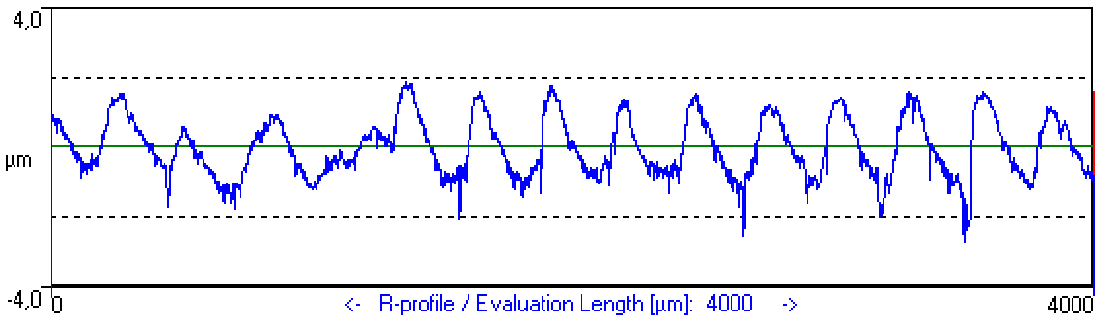
File: R2_100%   Profile no.: 2   Specimenmark: 0393341   26-04-2010



Ra 0,803
Rz 4,586

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

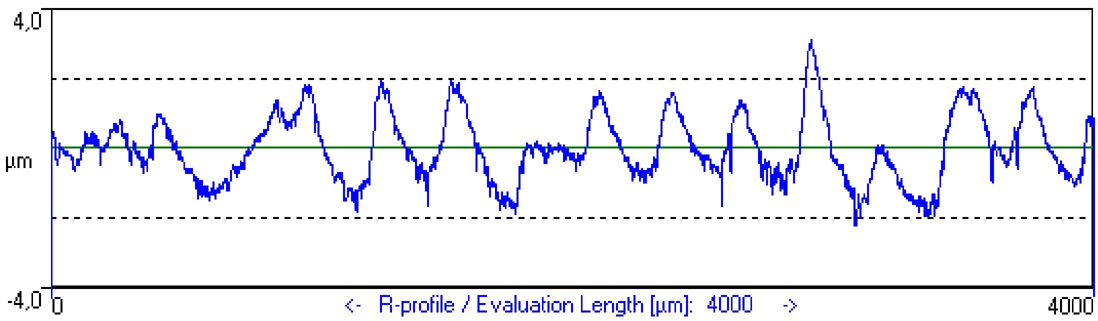
File: R2_100%   Profile no.: 3   Specimenmark: 0393341   26-04-2010



Ra 0,708
Rz 3,758

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: R2_100%   Profile no.: 4   Specimenmark: 0393341   26-04-2010



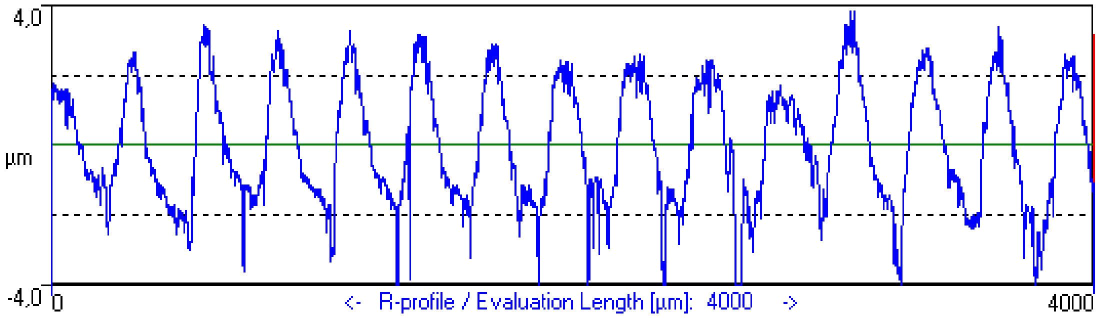
Ra 0,750
Rz 3,758

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator A – 26/04 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R3 – OIL (R0.3/M)

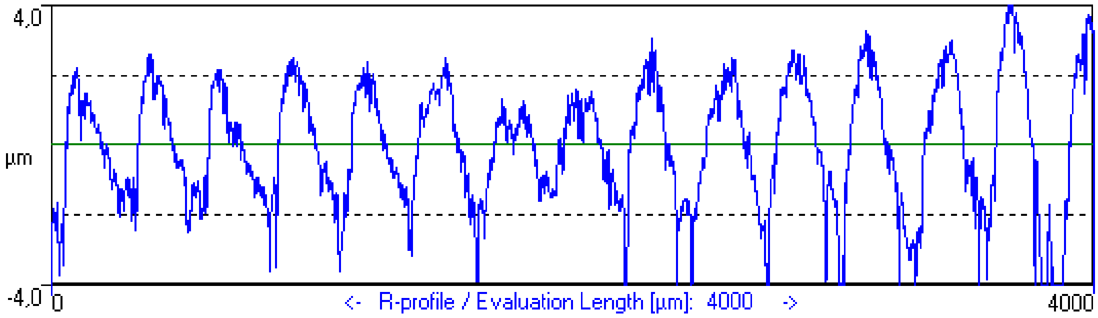
File: R3_100% Profile no.: 1 Specimenmark: 0393341 26-04-2010



Ra 1,511
Rz 8,220

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

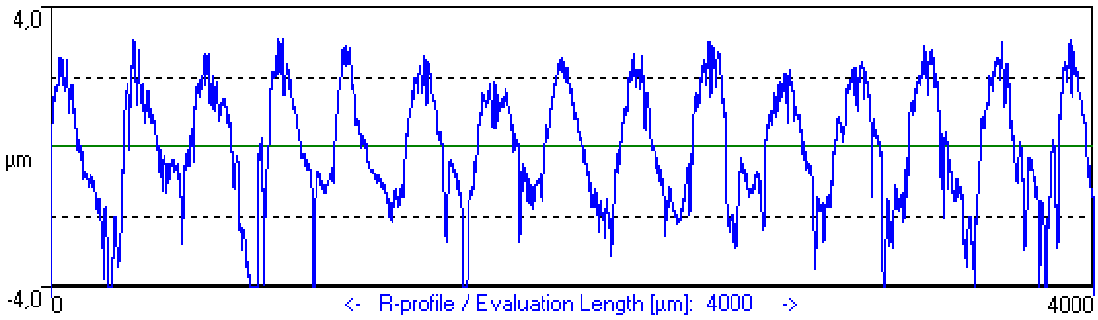
File: R3_100% Profile no.: 2 Specimenmark: 0393341 26-04-2010



Ra 1,509
Rz 8,384

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

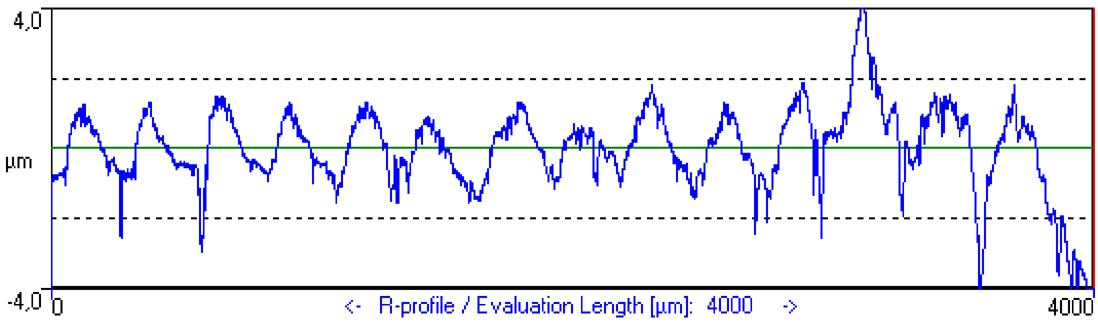
File: R3_100% Profile no.: 3 Specimenmark: 0393341 26-04-2010



Ra 1,454
Rz 8,740

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: R3_100% Profile no.: 4 Specimenmark: 0393341 26-04-2010



Ra 0,885
Rz 5,108

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

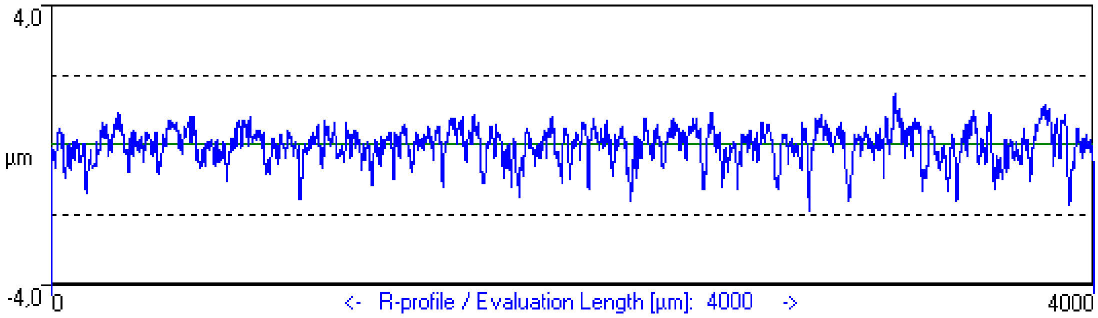
Appendix J5: Surface roughness measurement

Operator D: 3/5-2010

Operator D – 03/05 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P1 – 1% oil concentration (P0.3/W1)

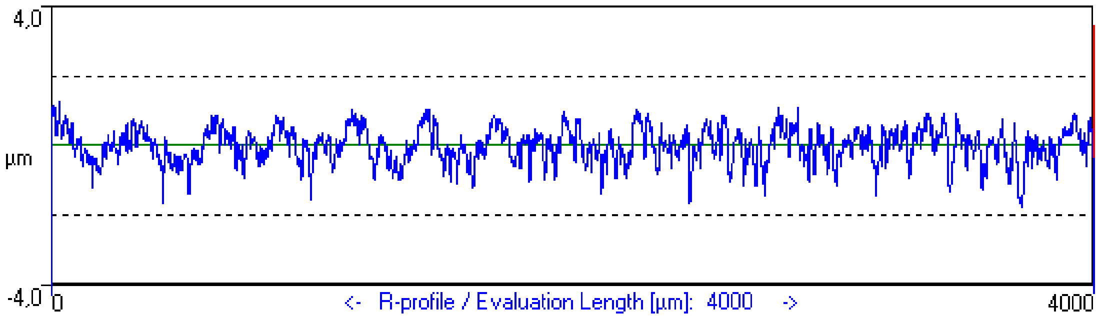
File: P1_1%   Profile no.: 1   Specimenmark: 0393341   03-05-2010



Ra 0,368
Rz 2,616

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

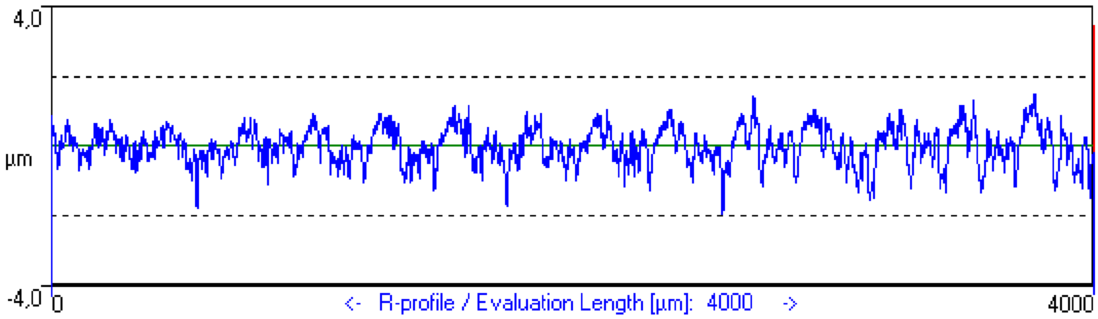
File: P1_1%   Profile no.: 2   Specimenmark: 0393341   03-05-2010



Ra 0,389
Rz 2,664

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

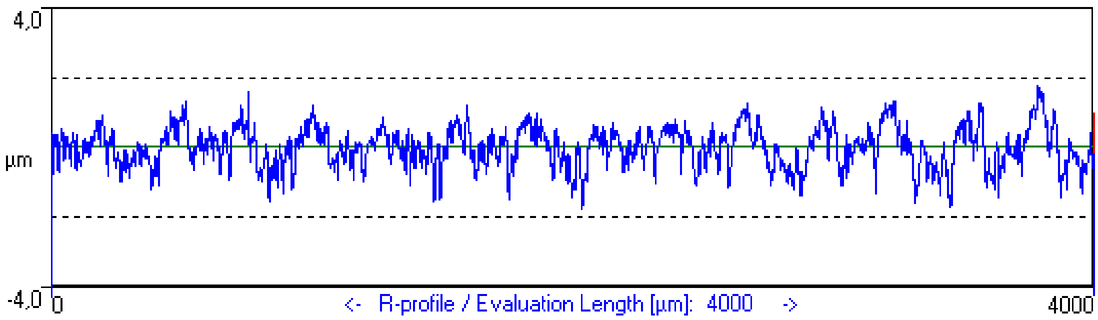
File: P1_1%   Profile no.: 3   Specimenmark: 0393341   03-05-2010



Ra 0,416
Rz 2,854

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: P1_1%   Profile no.: 4   Specimenmark: 0393341   03-05-2010



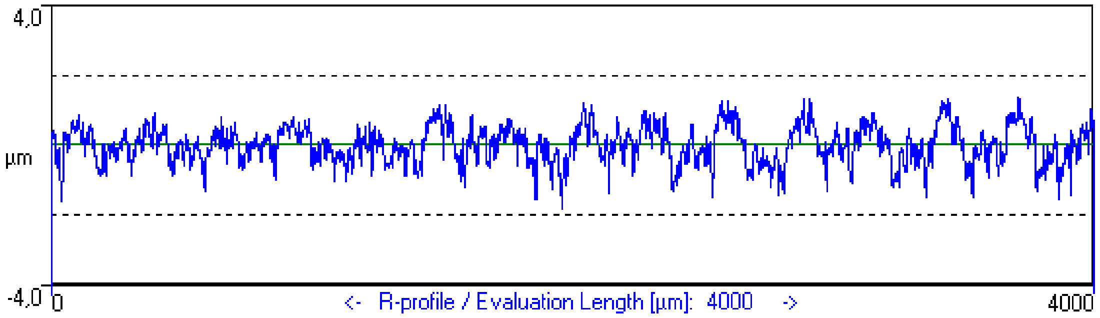
Ra 0,458
Rz 2,882

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator D – 03/05 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P2 – 1% oil concentration (P0.3/W1)

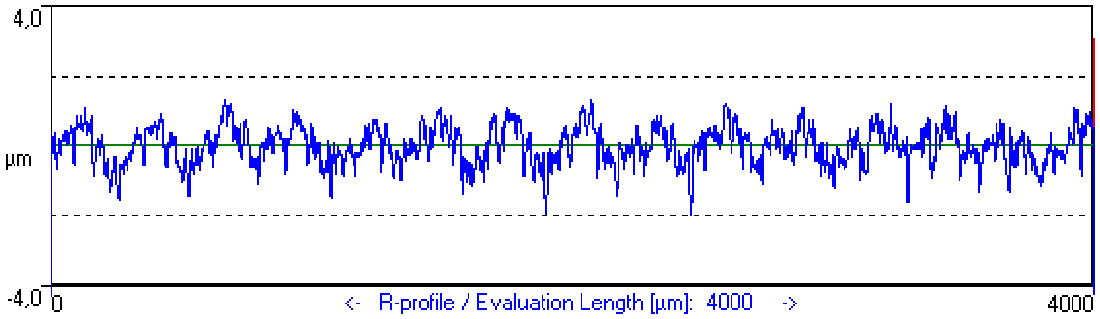
File: P2_1%   Profile no.: 1   Specimenmark: 0393341   03-05-2010



Ra 0,427
Rz 2,728

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

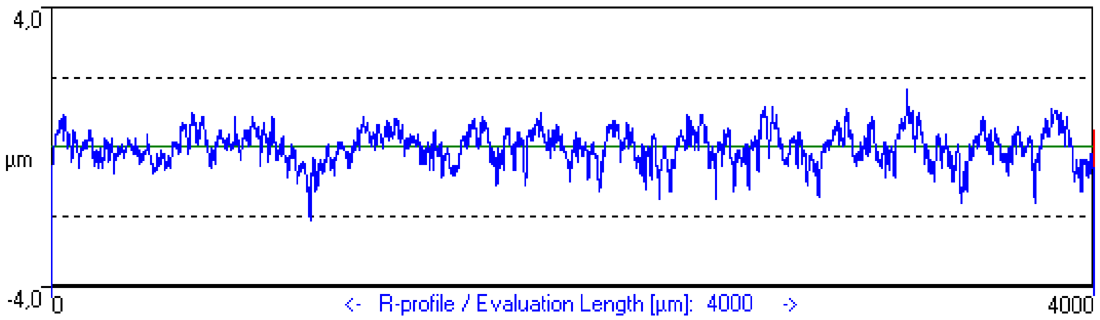
File: P2_1%   Profile no.: 2   Specimenmark: 0393341   03-05-2010



Ra 0,426
Rz 2,936

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

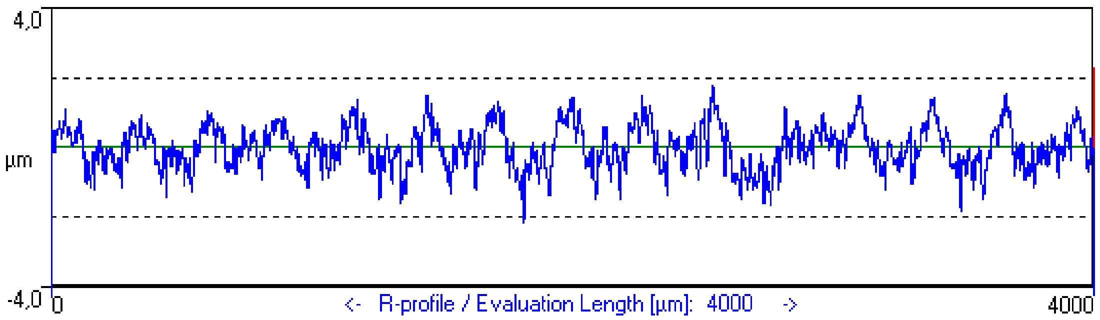
File: P2_1%   Profile no.: 3   Specimenmark: 0393341   03-05-2010



Ra 0,382
Rz 2,610

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: P2_1%   Profile no.: 4   Specimenmark: 0393341   03-05-2010



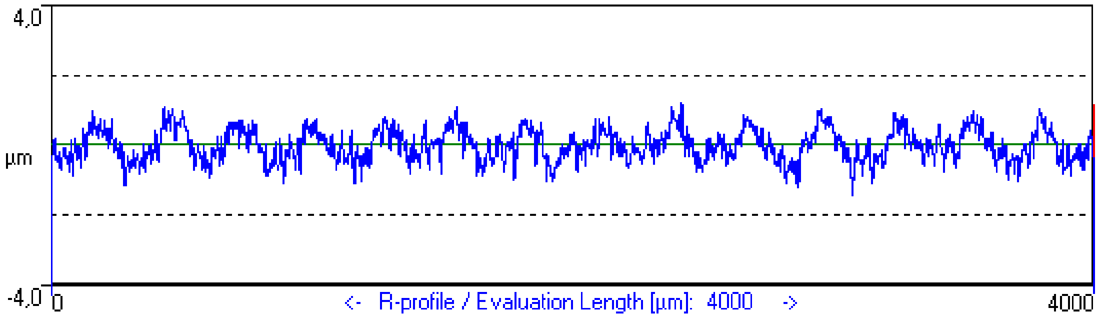
Ra 0,499
Rz 3,192

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator D – 03/05 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P3 – 1% oil concentration (P0.3/W1)

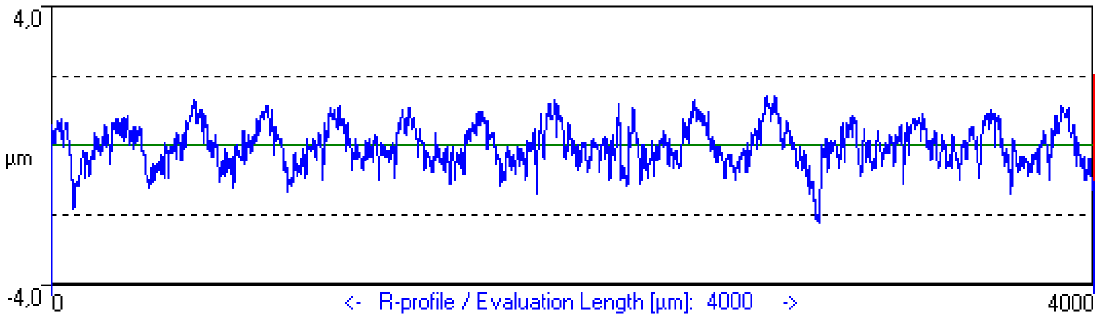
File: P3_1% Profile no.: 1 Specimenmark: 0393341 03-05-2010



Ra 0,369
Rz 2,244

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

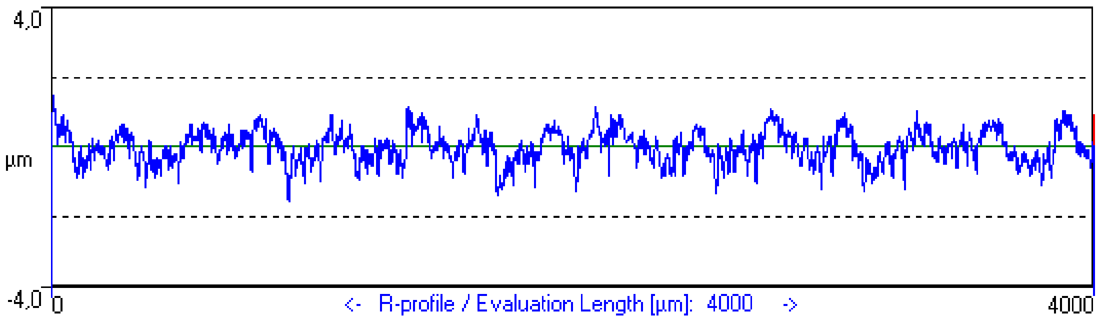
File: P3_1% Profile no.: 2 Specimenmark: 0393341 03-05-2010



Ra 0,461
Rz 2,878

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

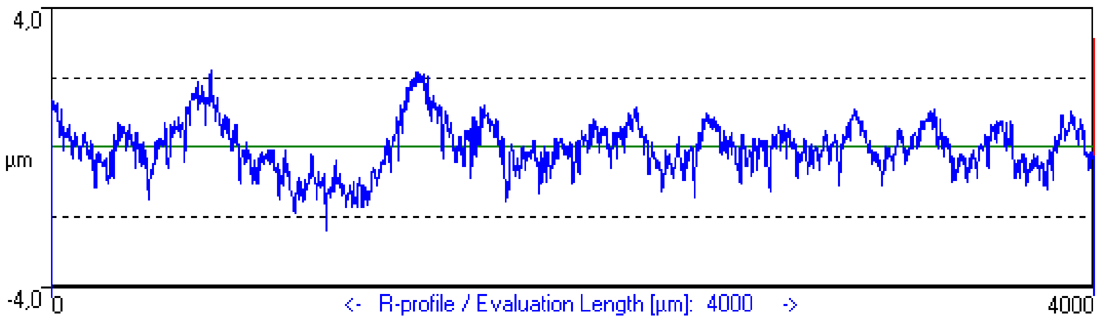
File: P3_1% Profile no.: 3 Specimenmark: 0393341 03-05-2010



Ra 0,367
Rz 2,476

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: P3_1% Profile no.: 4 Specimenmark: 0393341 03-05-2010



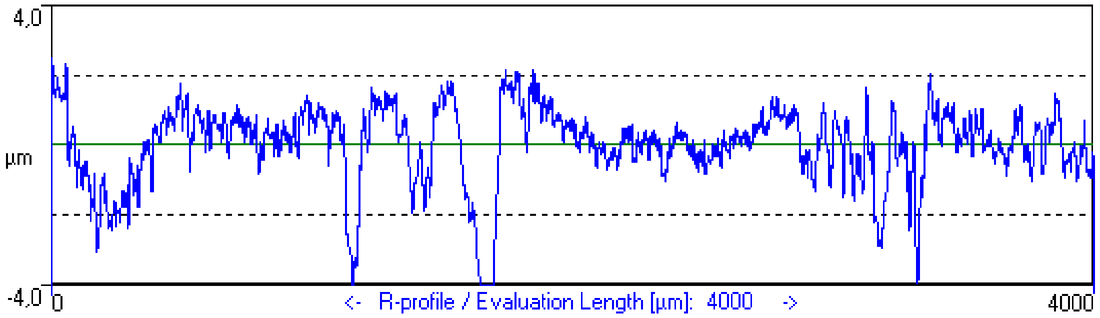
Ra 0,552
Rz 3,146

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator D – 03/05 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R1 – 1% oil concentration (R0.3/W1)

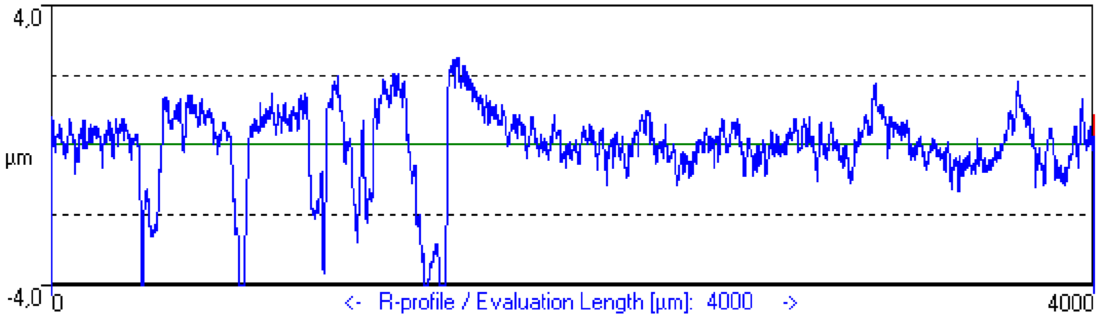
File: R1_1% Profile no.: 1 Specimenmark: 0393341 03-05-2010



Ra 0,826
Rz 6,032

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

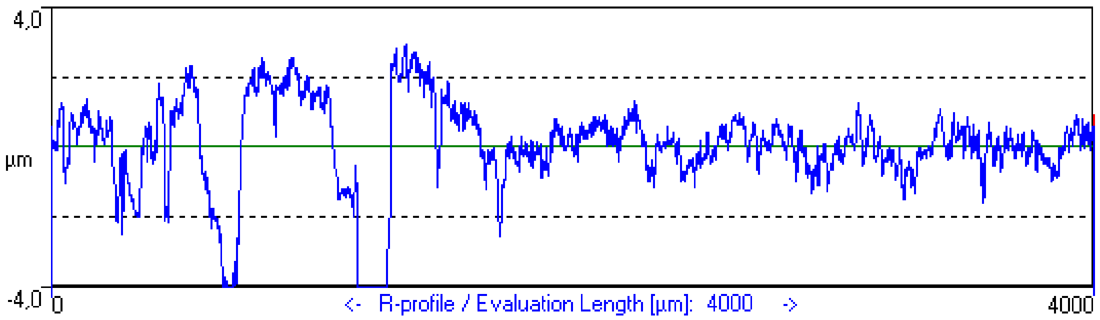
File: R1_1% Profile no.: 2 Specimenmark: 0393341 03-05-2010



Ra 0,756
Rz 5,114

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

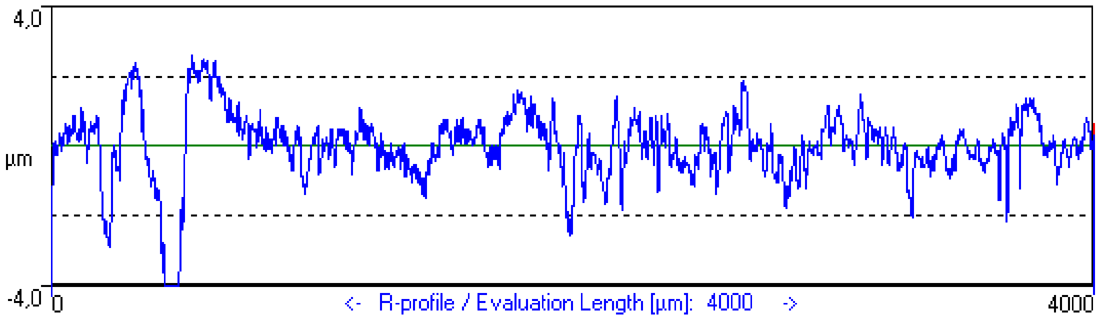
File: R1_1% Profile no.: 3 Specimenmark: 0393341 03-05-2010



Ra 0,954
Rz 5,544

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: R1_1% Profile no.: 4 Specimenmark: 0393341 03-05-2010



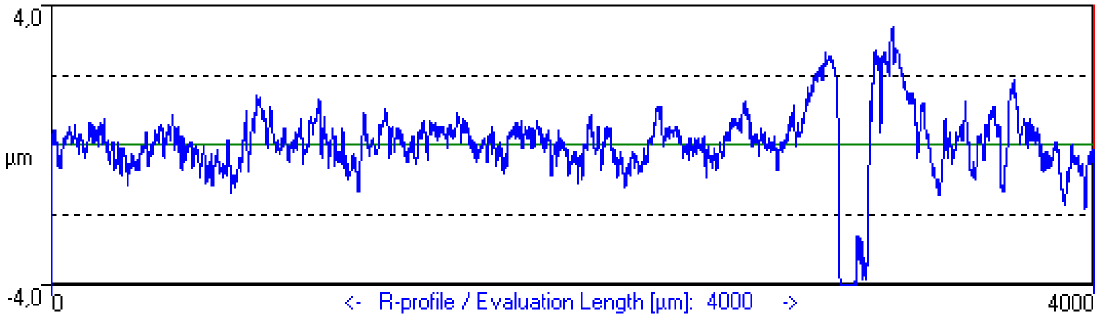
Ra 0,696
Rz 4,562

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator D – 03/05 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R2 – 1% oil concentration (R0.3/W1)

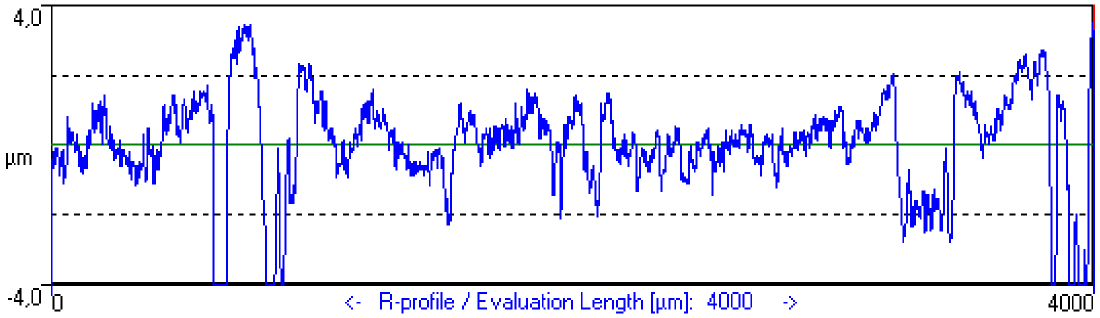
File: R2_1% Profile no.: 1 Specimenmark: 0393341 03-05-2010



Ra 0,687
Rz 5,370

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

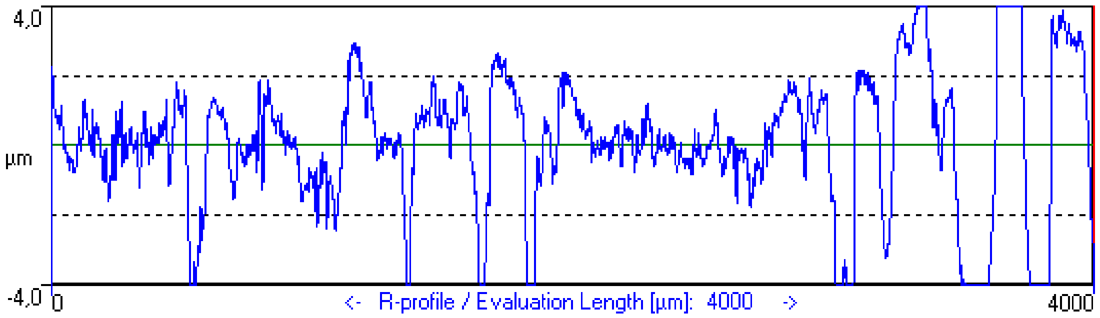
File: R2_1% Profile no.: 2 Specimenmark: 0393341 03-05-2010



Ra 1,037
Rz 7,094

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

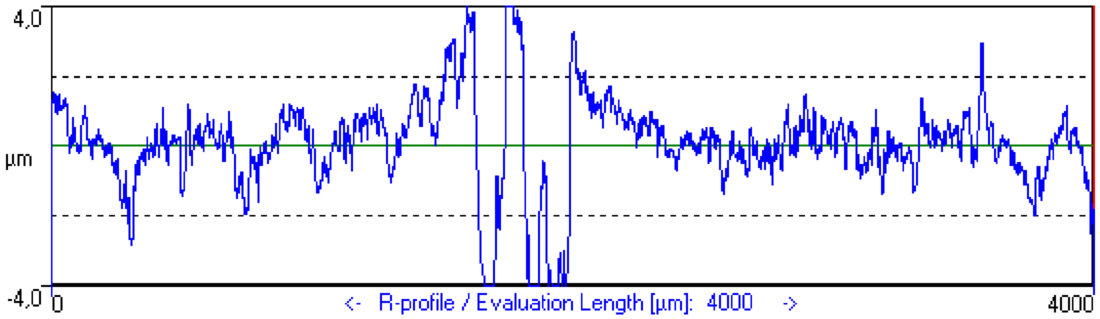
File: R2_1% Profile no.: 3 Specimenmark: 0393341 03-05-2010



Ra 1,645
Rz 10,718

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: R2_1% Profile no.: 4 Specimenmark: 0393341 03-05-2010

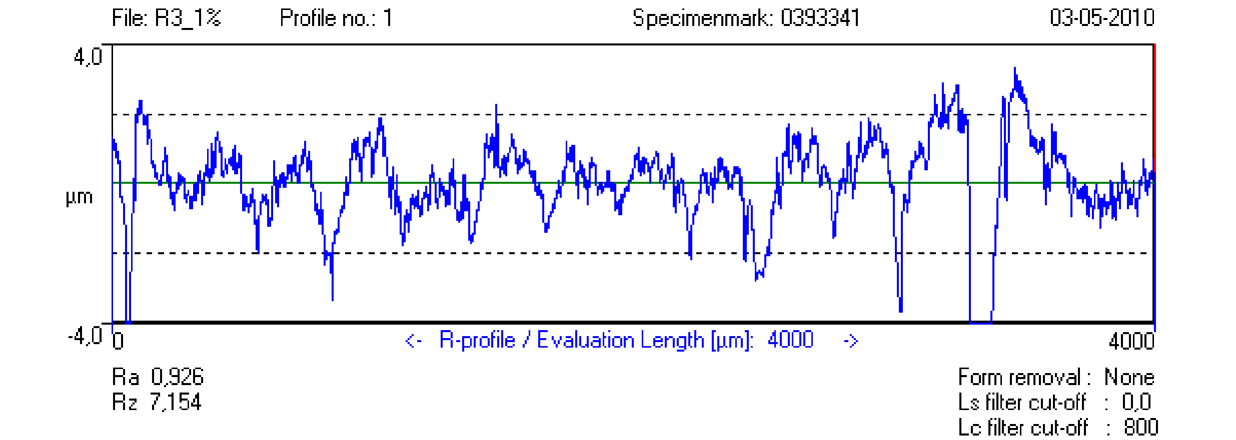


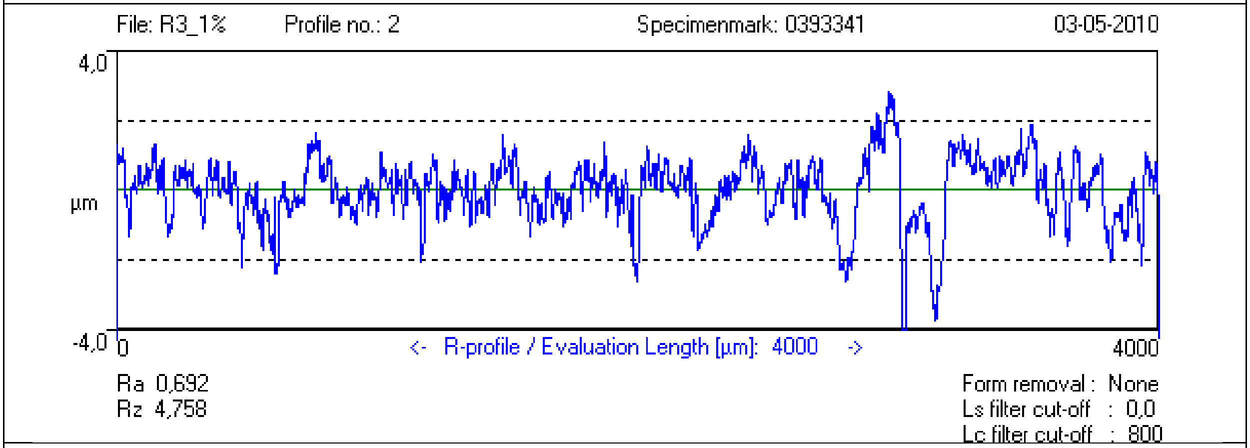
Ra 0,950
Rz 6,344

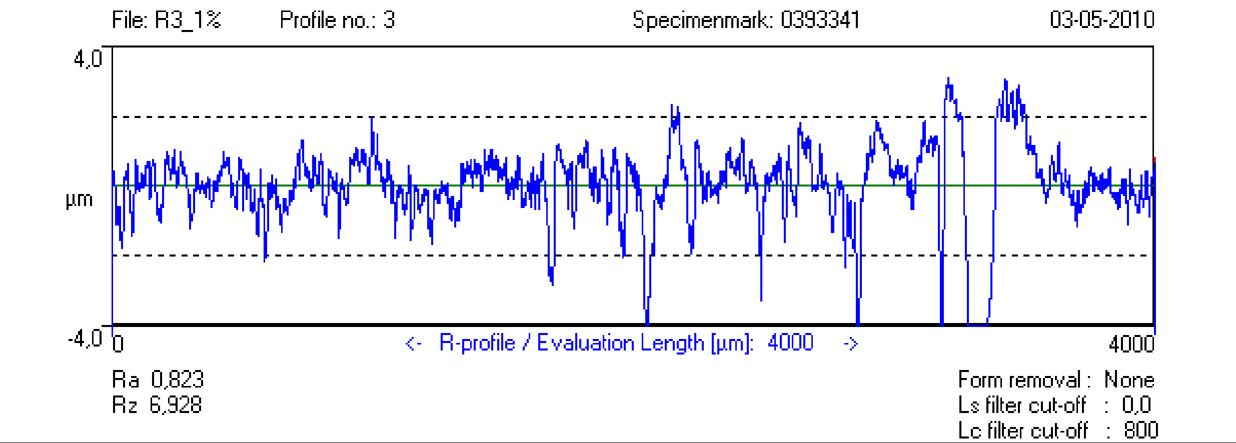
Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

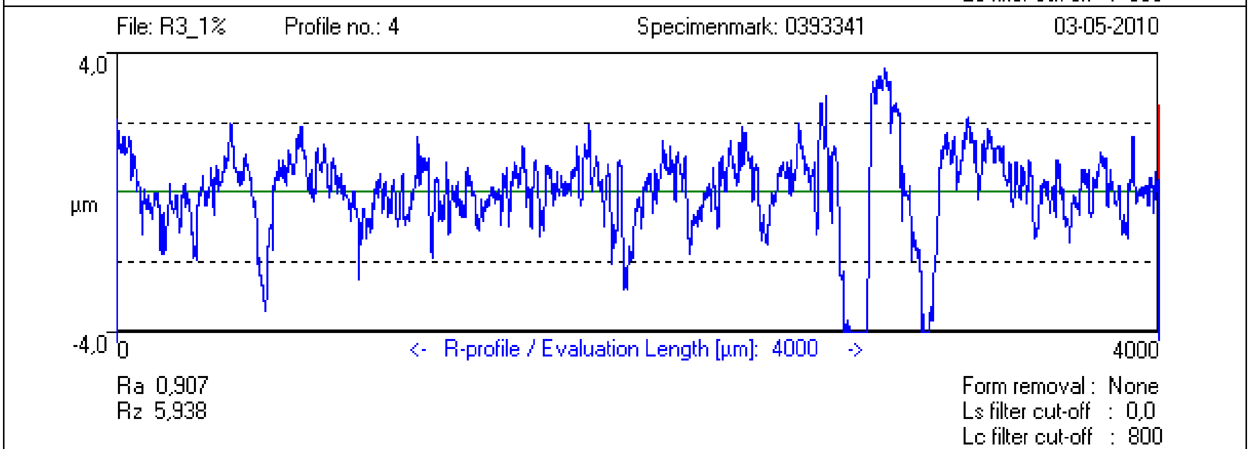
Operator D – 03/05 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R3 – 1% oil concentration (R0.3/W1)





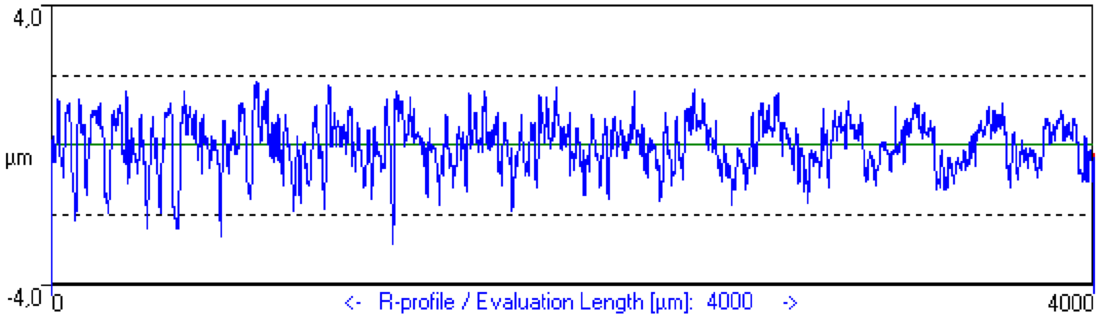




Operator D – 03/05 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P1 – 10% oil concentration (P0.3/W2)

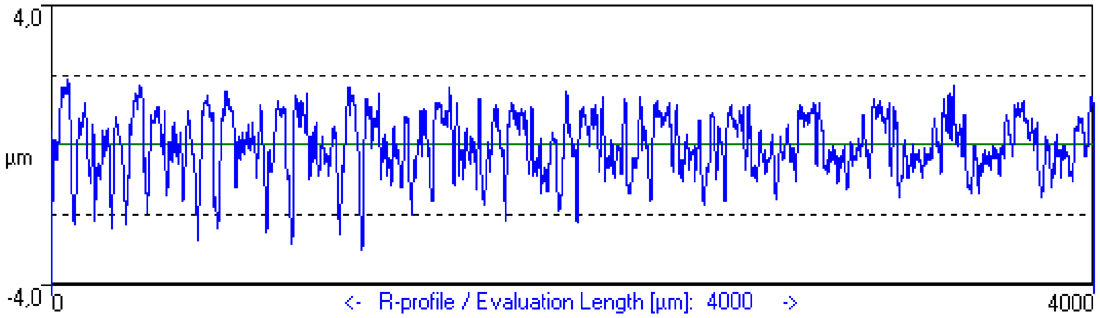
File: P1_10% Profile no.: 1 Specimenmark: 0393341 03-05-2010



Ra 0,585
Rz 3,648

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

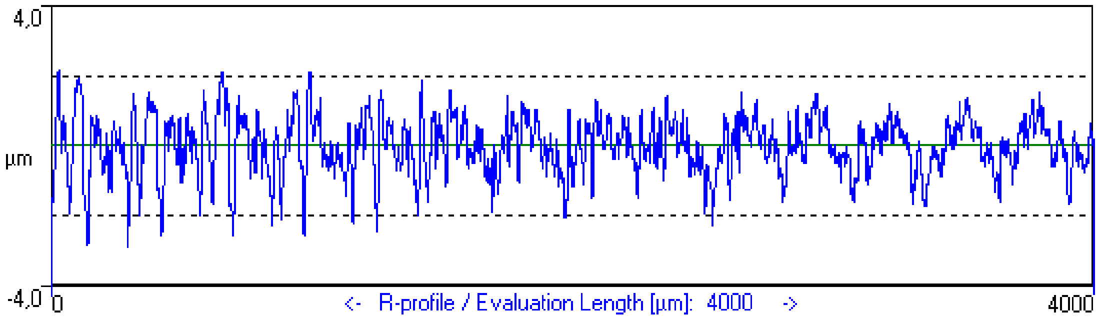
File: P1_10% Profile no.: 2 Specimenmark: 0393341 03-05-2010



Ra 0,685
Rz 3,850

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

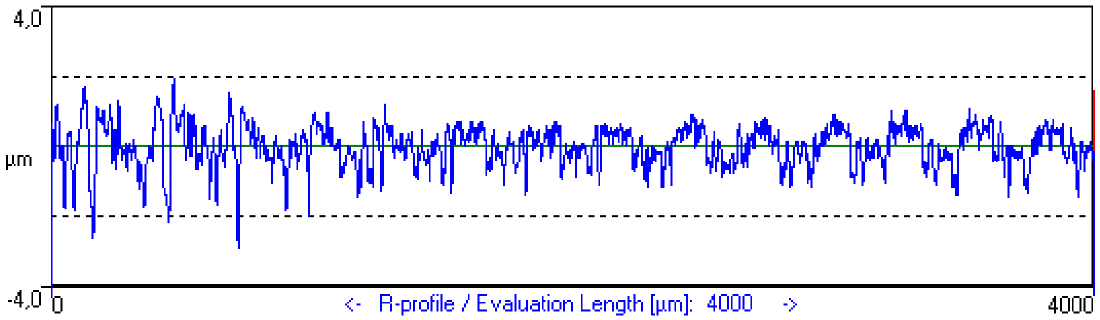
File: P1_10% Profile no.: 3 Specimenmark: 0393341 03-05-2010



Ra 0,643
Rz 4,052

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: P1_10% Profile no.: 4 Specimenmark: 0393341 03-05-2010



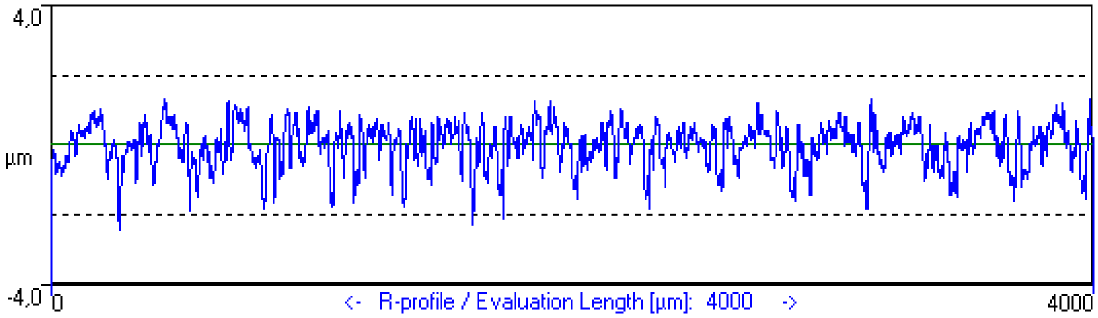
Ra 0,453
Rz 2,946

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator D – 03/05 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P2 – 10% oil concentration (P0.3/W2)

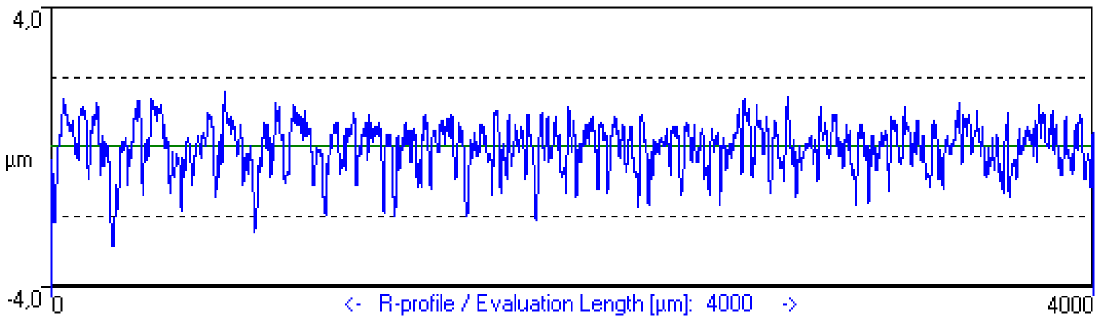
File: P2_10% Profile no.: 1 Specimenmark: 0393341 03-05-2010



Ra 0,495
Rz 3,250

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

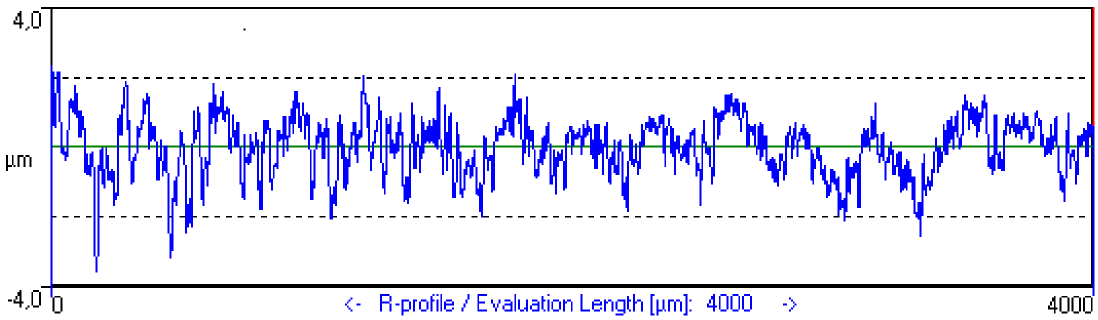
File: P2_10% Profile no.: 2 Specimenmark: 0393341 03-05-2010



Ra 0,524
Rz 3,336

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

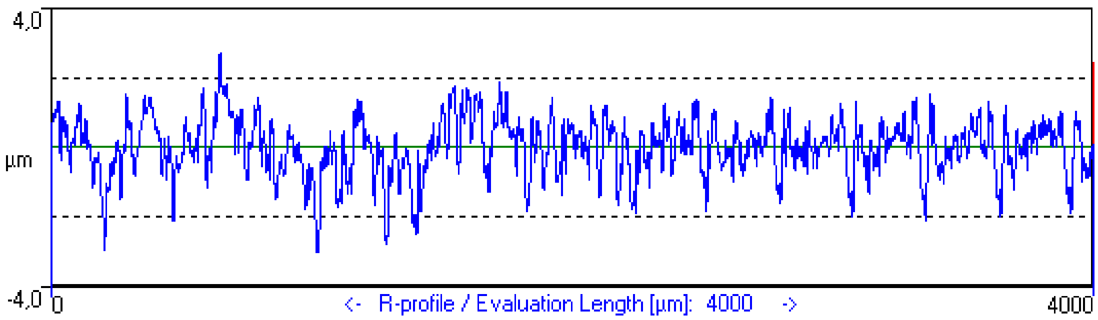
File: P2_10% Profile no.: 3 Specimenmark: 0393341 03-05-2010



Ra 0,655
Rz 4,334

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: P2_10% Profile no.: 4 Specimenmark: 0393341 03-05-2010



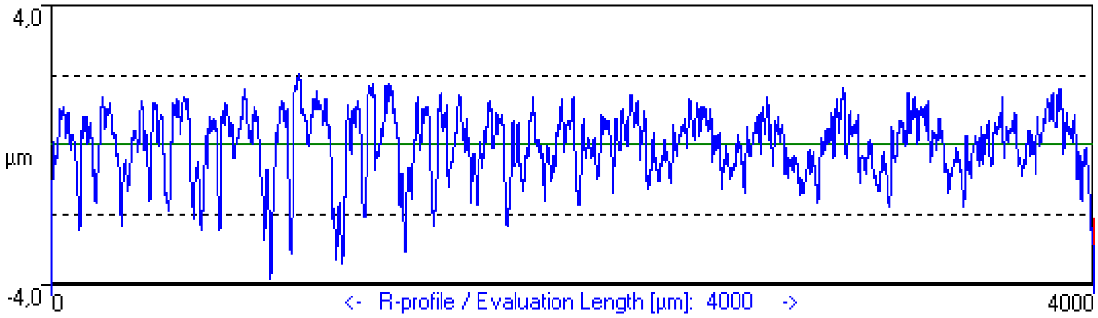
Ra 0,635
Rz 4,238

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator D – 03/05 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P3 – 10% oil concentration (P0.3/W2)

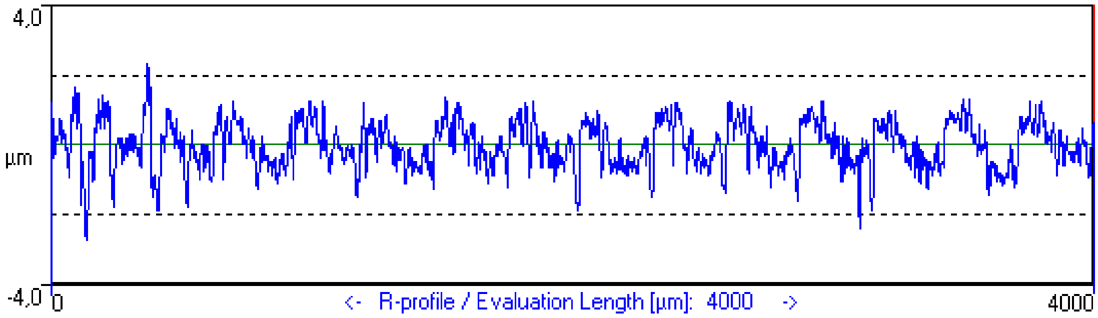
File: P3_10%   Profile no.: 1   Specimenmark: 0393341   03-05-2010



Ra 0,736
Rz 4,330

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

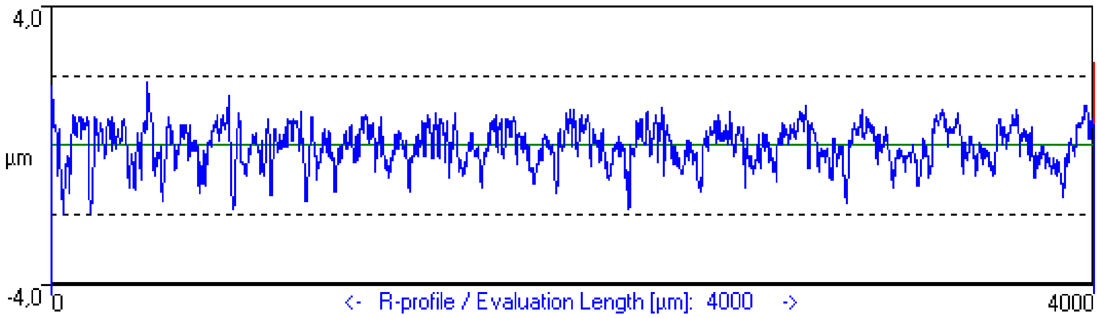
File: P3_10%   Profile no.: 2   Specimenmark: 0393341   03-05-2010



Ra 0,537
Rz 3,484

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

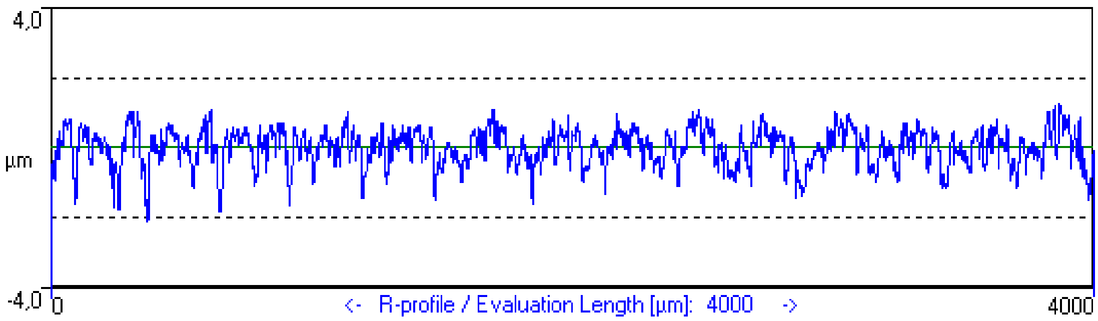
File: P3_10%   Profile no.: 3   Specimenmark: 0393341   03-05-2010



Ra 0,456
Rz 2,948

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: P3_10%   Profile no.: 4   Specimenmark: 0393341   03-05-2010



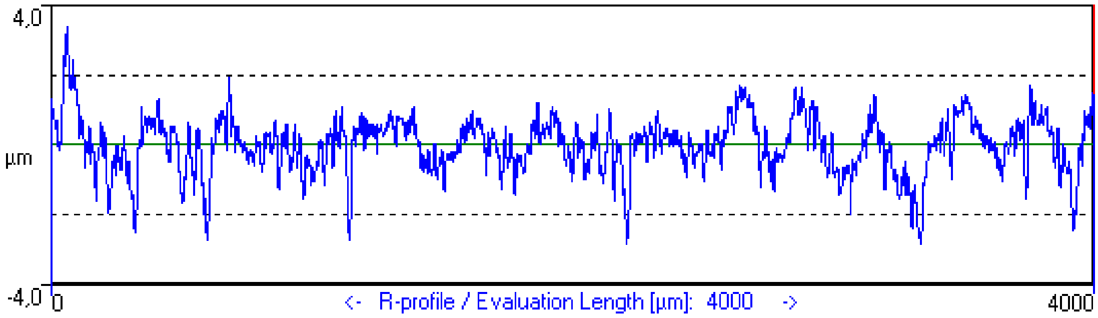
Ra 0,418
Rz 2,774

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator D – 03/05 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R1 – 10% oil concentration (R0.3/W2)

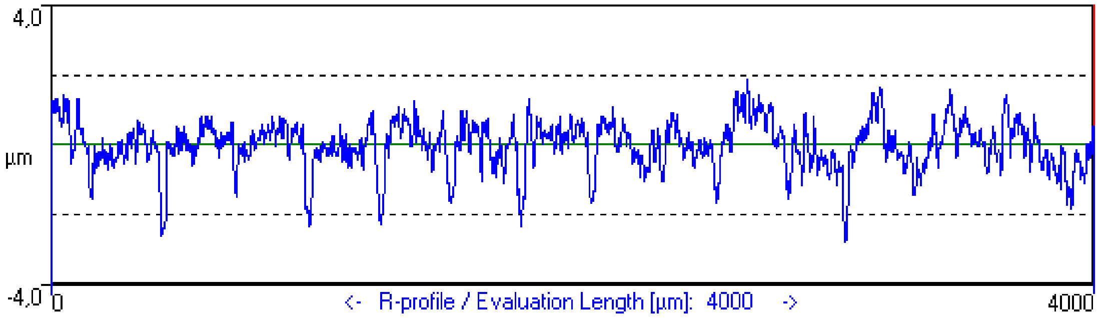
File: R1_10% Profile no.: 1 Specimenmark: 0393341 03-05-2010



Ra 0,609
Rz 4,440

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

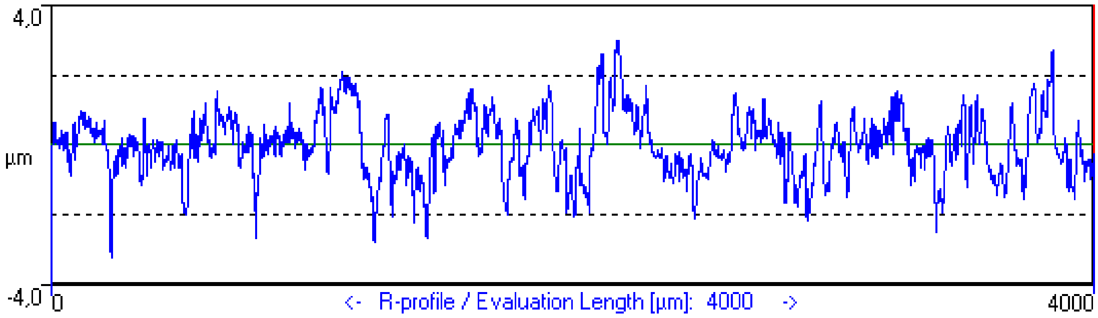
File: R1_10% Profile no.: 2 Specimenmark: 0393341 03-05-2010



Ra 0,514
Rz 3,866

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

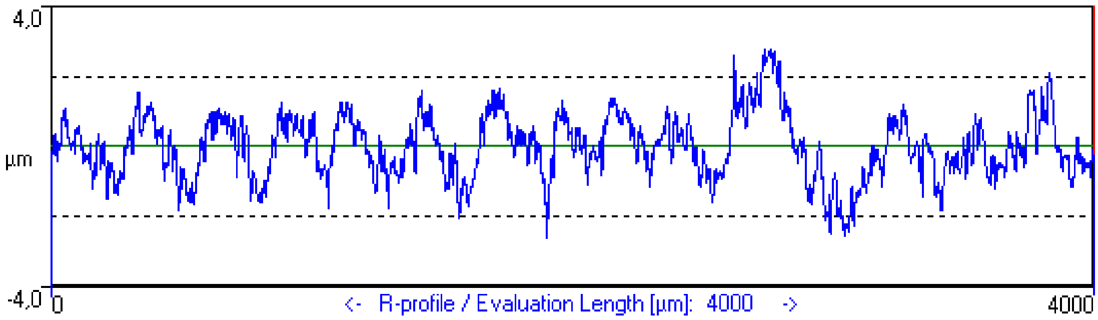
File: R1_10% Profile no.: 3 Specimenmark: 0393341 03-05-2010



Ra 0,691
Rz 4,706

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: R1_10% Profile no.: 4 Specimenmark: 0393341 03-05-2010



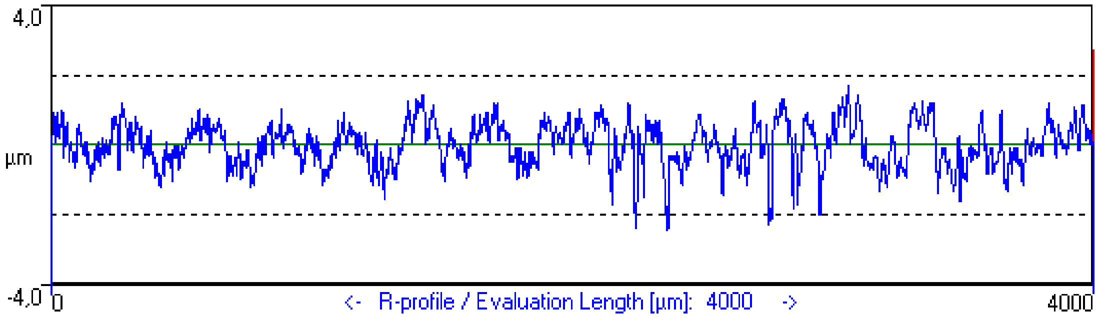
Ra 0,713
Rz 4,108

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator D – 03/05 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R2 – 10% oil concentration (R0.3/W2)

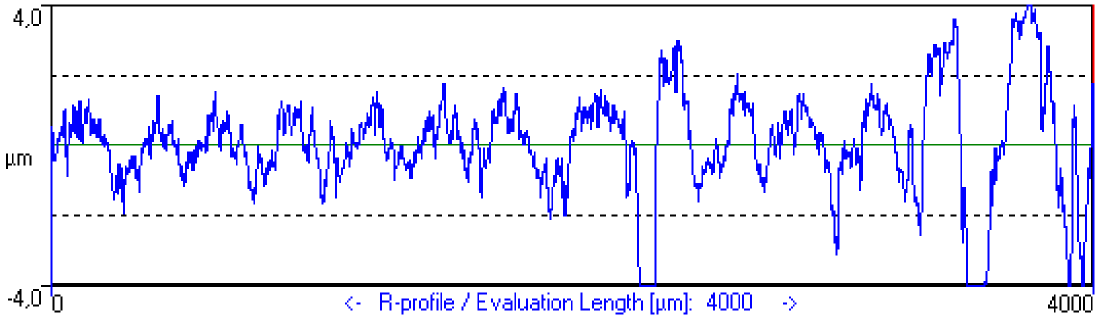
File: R2_10% Profile no.: 1 Specimenmark: 0393341 03-05-2010



Ra 0,508
Rz 3,174

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

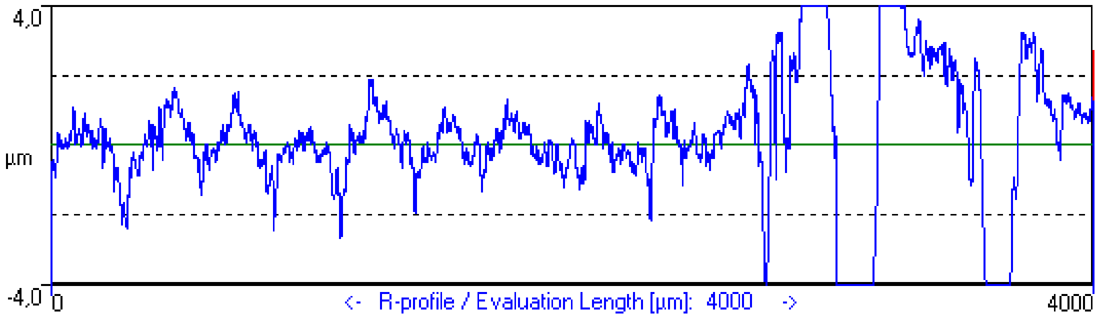
File: R2_10% Profile no.: 2 Specimenmark: 0393341 03-05-2010



Ra 1,134
Rz 7,522

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

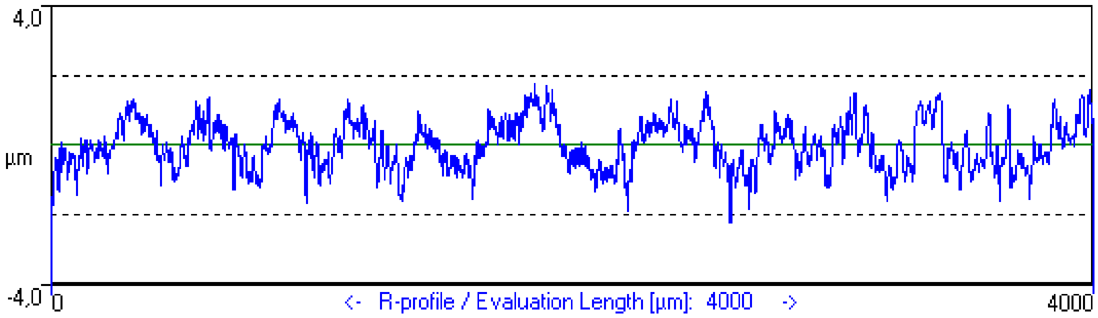
File: R2_10% Profile no.: 3 Specimenmark: 0393341 03-05-2010



Ra 1,660
Rz 10,426

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: R2_10% Profile no.: 4 Specimenmark: 0393341 03-05-2010



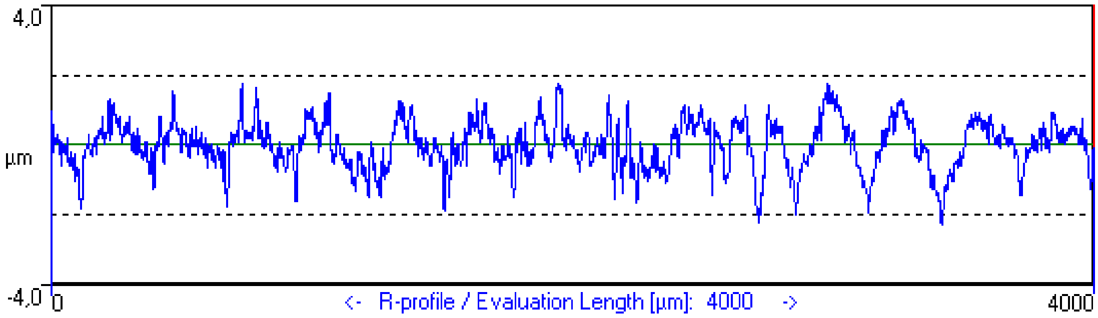
Ra 0,562
Rz 3,318

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator D – 03/05 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R3 – 10% oil concentration (R0.3/W2)

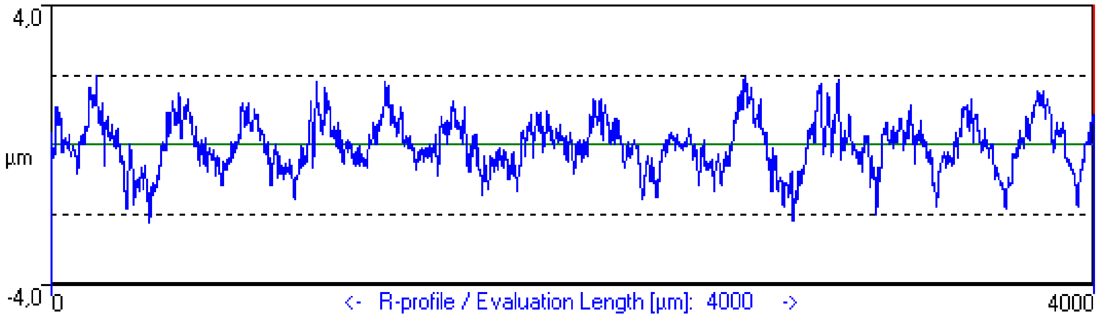
File: R3_10% Profile no.: 1 Specimenmark: 0393341 03-05-2010



Ra 0,537
Rz 3,574

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

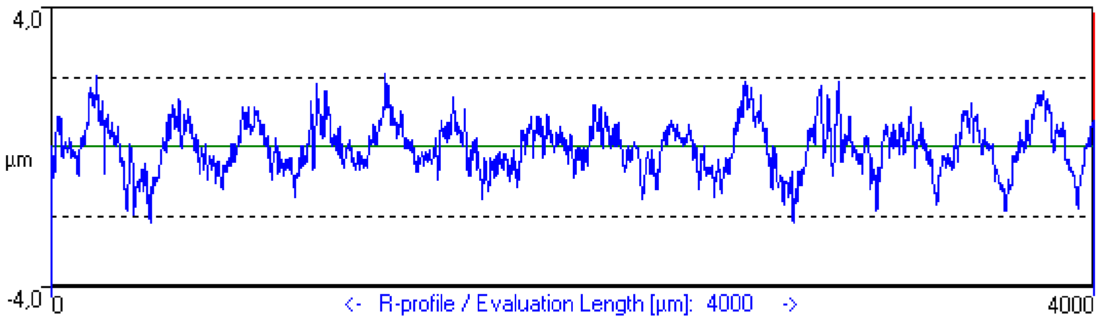
File: R3_10% Profile no.: 2 Specimenmark: 0393341 03-05-2010



Ra 0,567
Rz 3,594

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

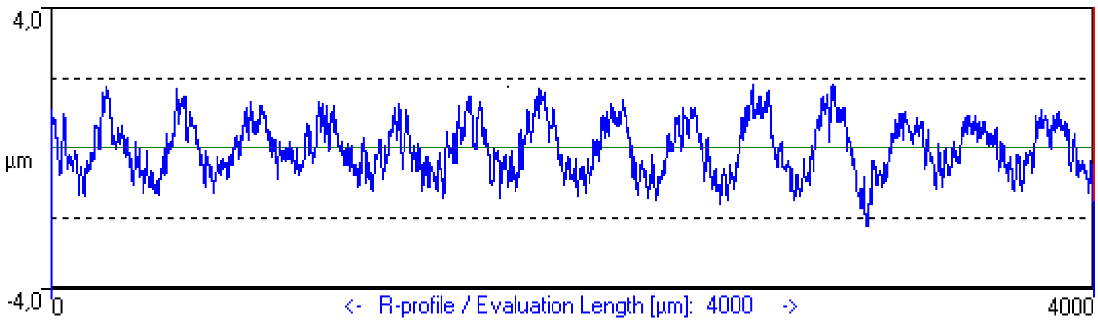
File: R3_10% Profile no.: 3 Specimenmark: 0393341 03-05-2010



Ra 0,562
Rz 3,576

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: R3_10% Profile no.: 4 Specimenmark: 0393341 03-05-2010



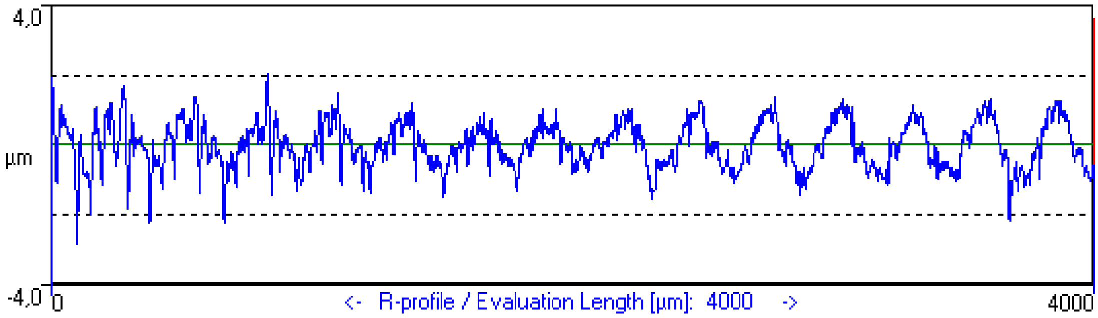
Ra 0,627
Rz 3,170

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator D – 03/05 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P1 – OIL (P0.3/M)

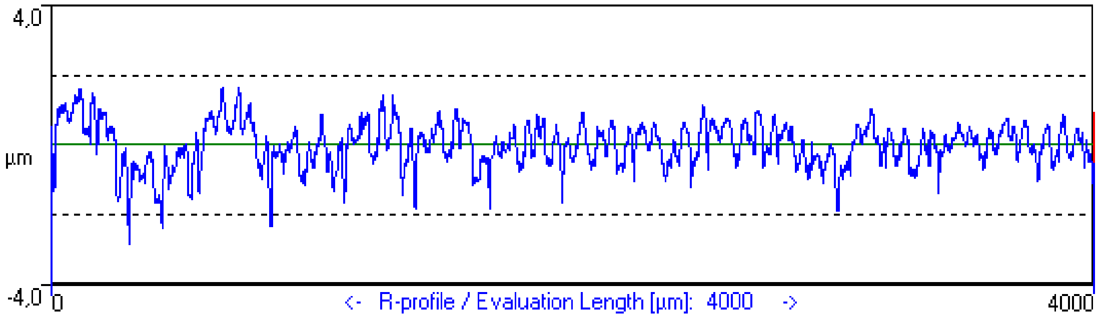
File: P1_100% Profile no.: 1 Specimenmark: 0393341 03-05-2010



Ra 0,537
Rz 3,420

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

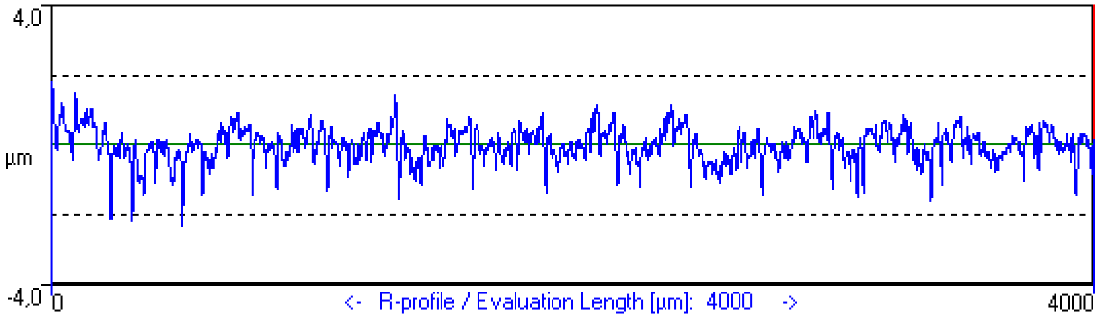
File: P1_100% Profile no.: 2 Specimenmark: 0393341 03-05-2010



Ra 0,494
Rz 3,240

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

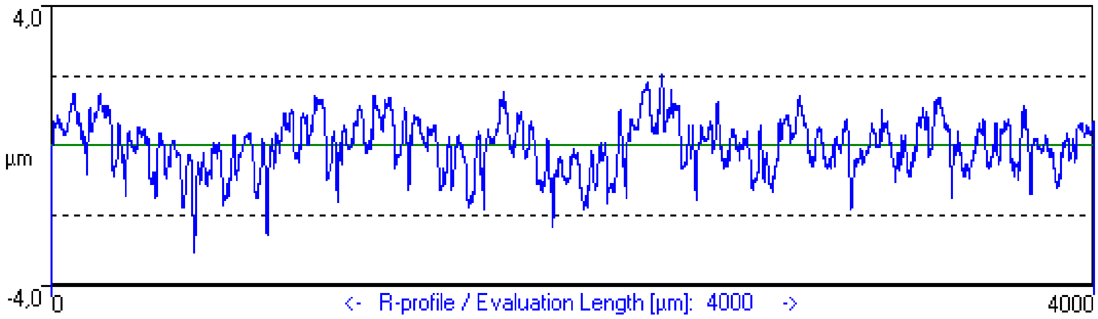
File: P1_100% Profile no.: 3 Specimenmark: 0393341 03-05-2010



Ra 0,371
Rz 2,916

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: P1_100% Profile no.: 4 Specimenmark: 0393341 03-05-2010



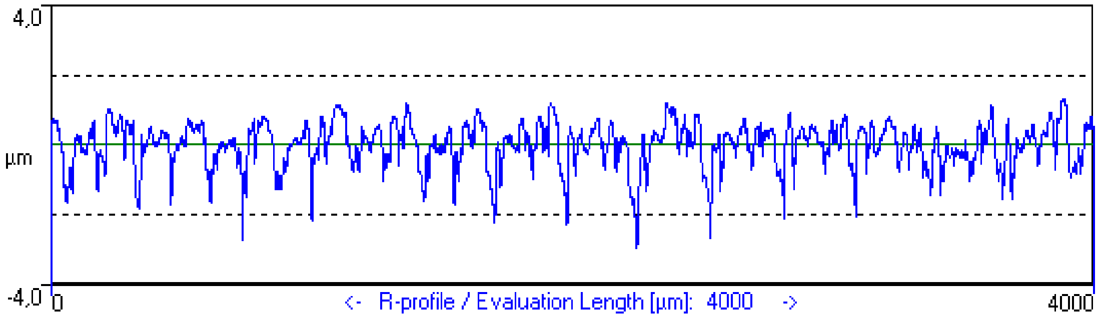
Ra 0,587
Rz 3,800

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator D – 03/05 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P2 – OIL (P0.3/M)

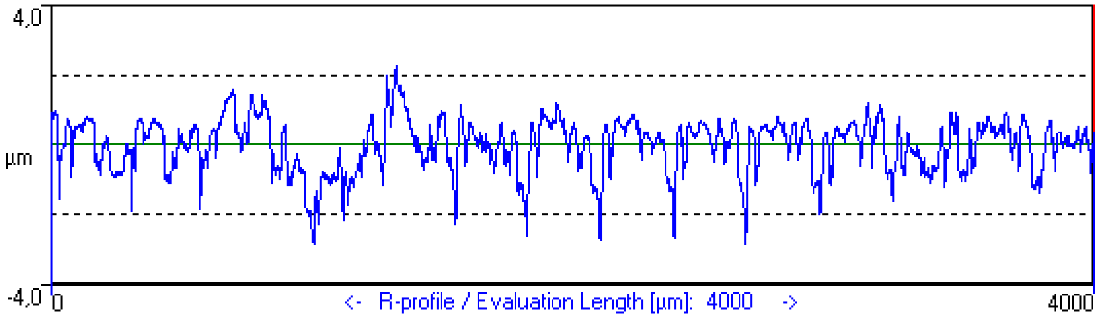
File: P2_100% Profile no.: 1 Specimenmark: 0393341 03-05-2010



Ra 0,486
Rz 3,526

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

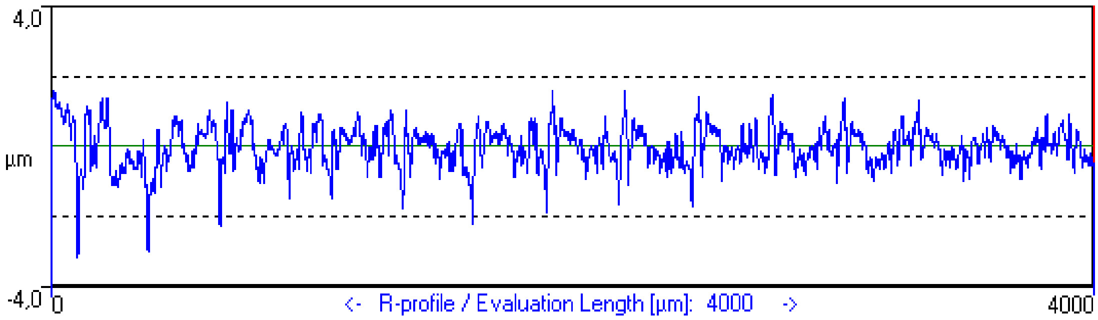
File: P2_100%.dat Profile no.: 2 Specimenmark: 0393341 03-05-2010



Ra 0,600
Rz 3,806
Rzmax 5,120

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

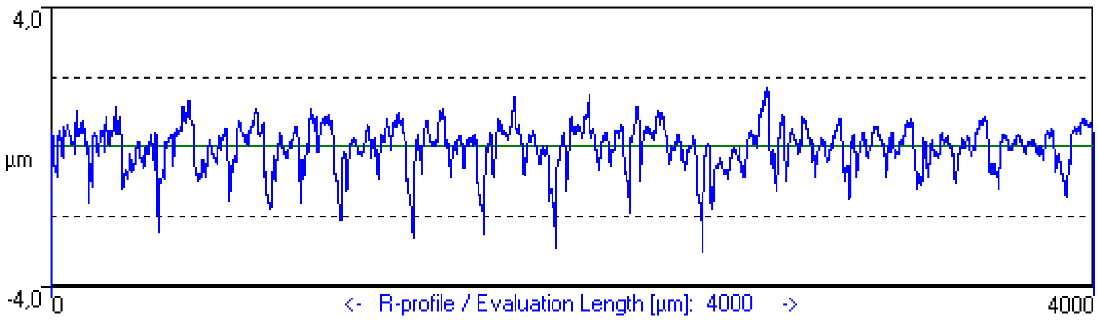
File: P2_100% Profile no.: 3 Specimenmark: 0393341 03-05-2010



Ra 0,440
Rz 3,380

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: P2_100% Profile no.: 4 Specimenmark: 0393341 03-05-2010



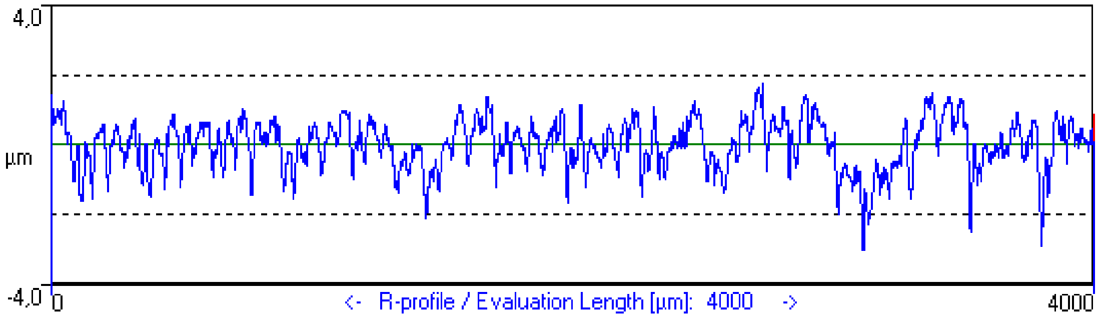
Ra 0,477
Rz 3,752

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator D – 03/05 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece P3 – OIL (P0.3/M)

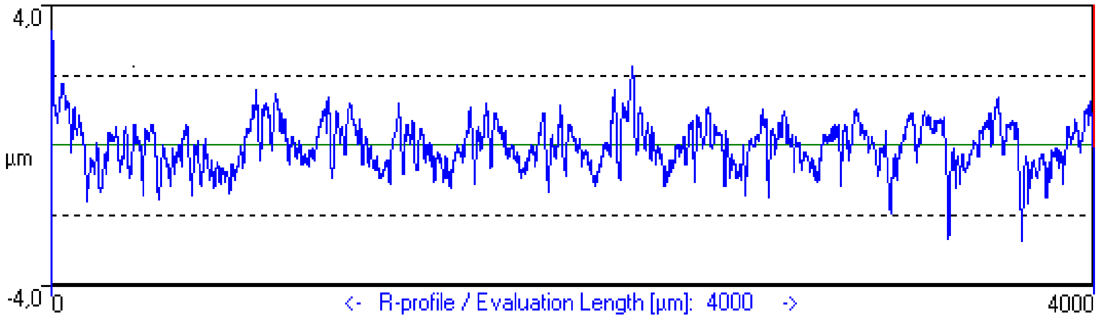
File: P3_100% Profile no.: 1 Specimenmark: 0393341 03-05-2010



Ra 0,563
Rz 3,700

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

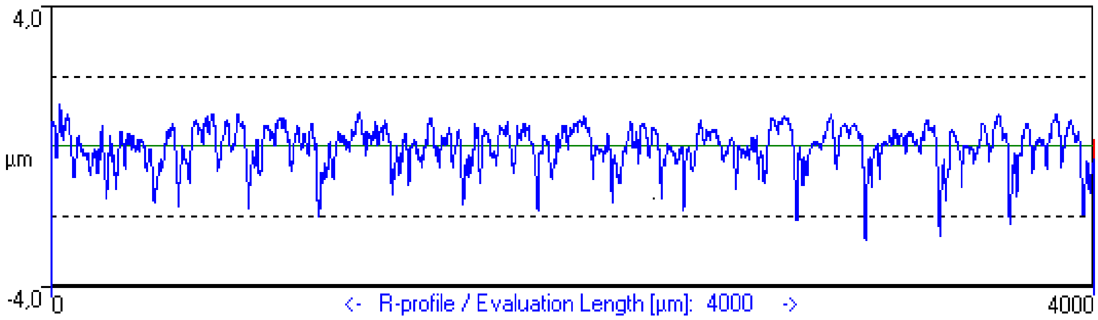
File: P3_100% Profile no.: 2 Specimenmark: 0393341 03-05-2010



Ra 0,519
Rz 3,562

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

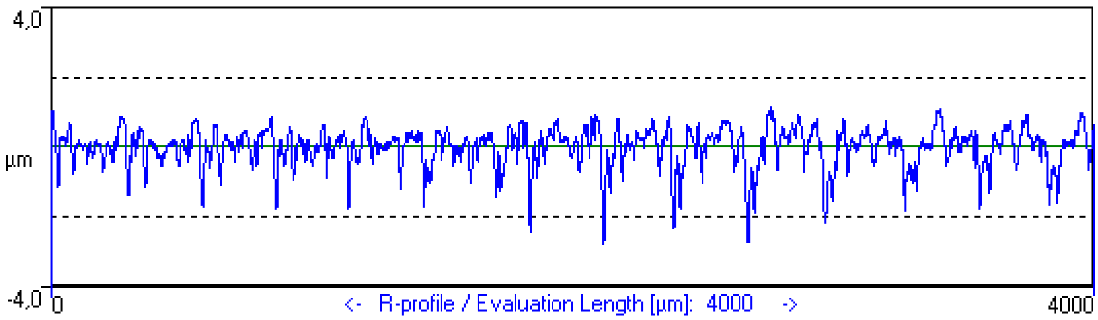
File: P3_100% Profile no.: 3 Specimenmark: 0393341 03-05-2010



Ra 0,431
Rz 3,118

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: P3_100% Profile no.: 4 Specimenmark: 0393341 03-05-2010



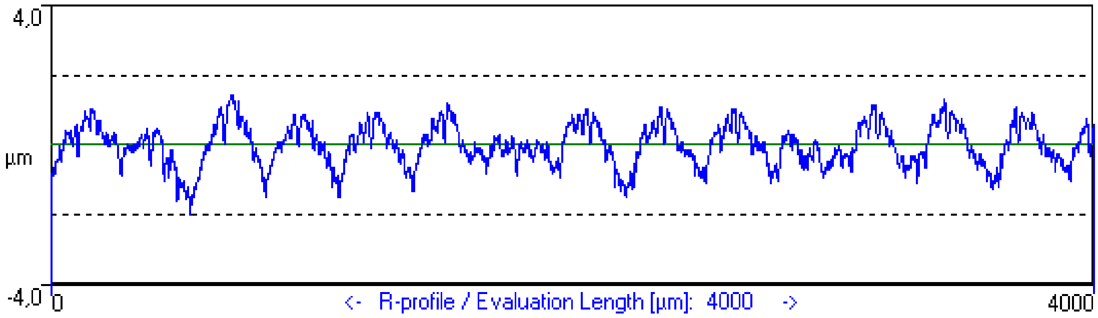
Ra 0,404
Rz 3,164

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator D – 03/05 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R1 – OIL (R0.3/M)

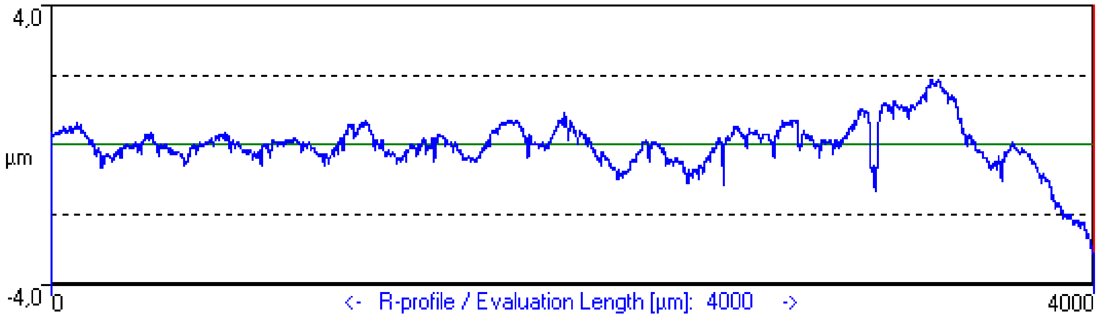
File: R1_100% Profile no.: 1 Specimenmark: 0393341 03-05-2010



Ra 0,472
Rz 2,708

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

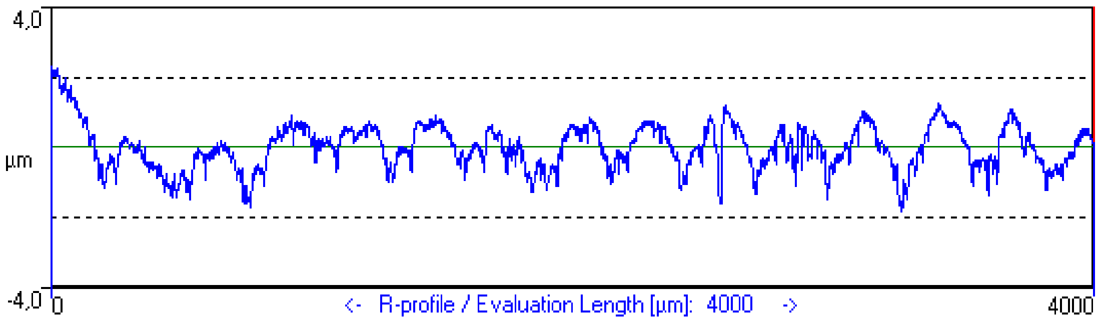
File: R1_100% Profile no.: 2 Specimenmark: 0393341 03-05-2010



Ra 0,457
Rz 2,396

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

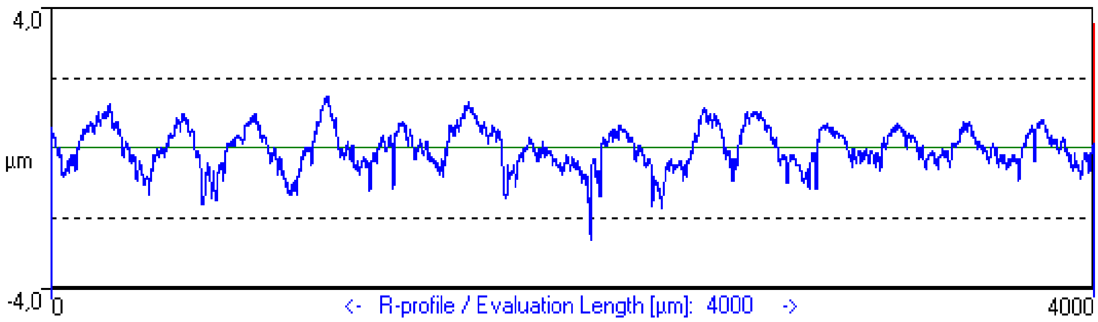
File: R1_100% Profile no.: 3 Specimenmark: 0393341 03-05-2010



Ra 0,516
Rz 2,788

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: R1_100% Profile no.: 4 Specimenmark: 0393341 03-05-2010



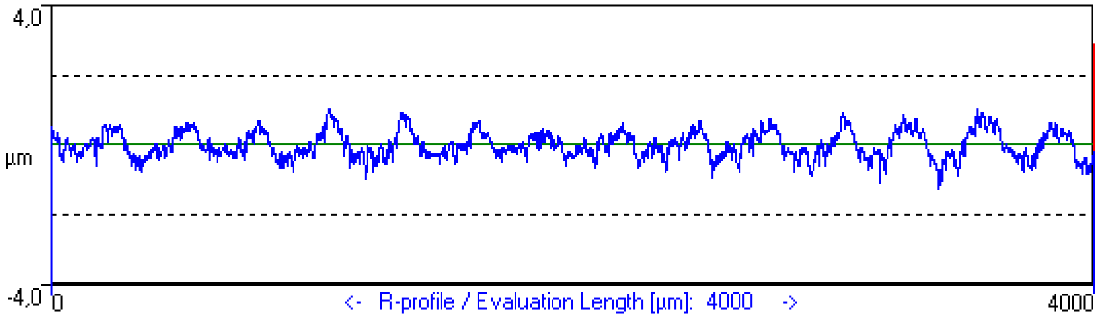
Ra 0,468
Rz 2,718

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator D – 03/05 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R2 – OIL (R0.3/M)

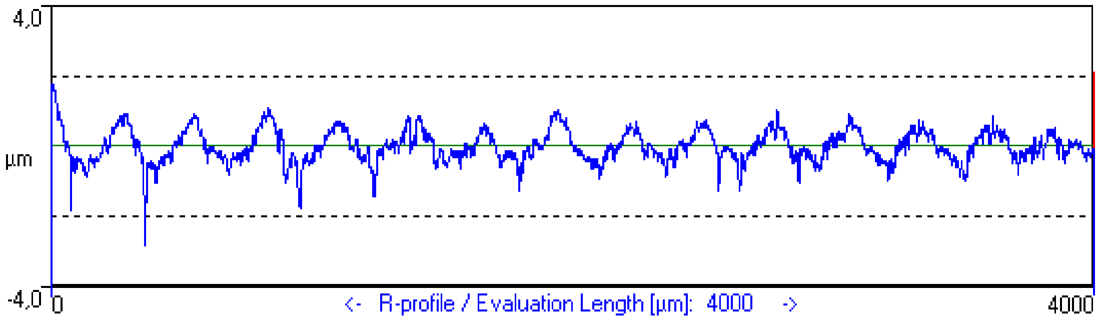
File: R2_100%   Profile no.: 1   Specimenmark: 0393341   03-05-2010



Ra 0,311
Rz 1,854

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

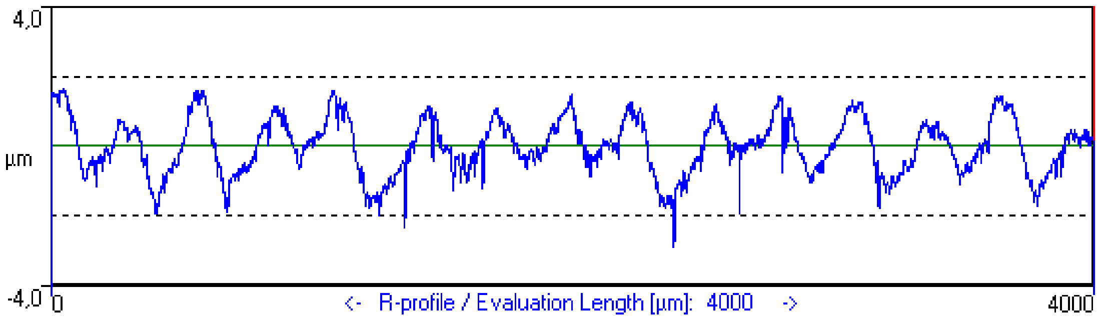
File: R2_100%   Profile no.: 2   Specimenmark: 0393341   03-05-2010



Ra 0,361
Rz 2,784

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

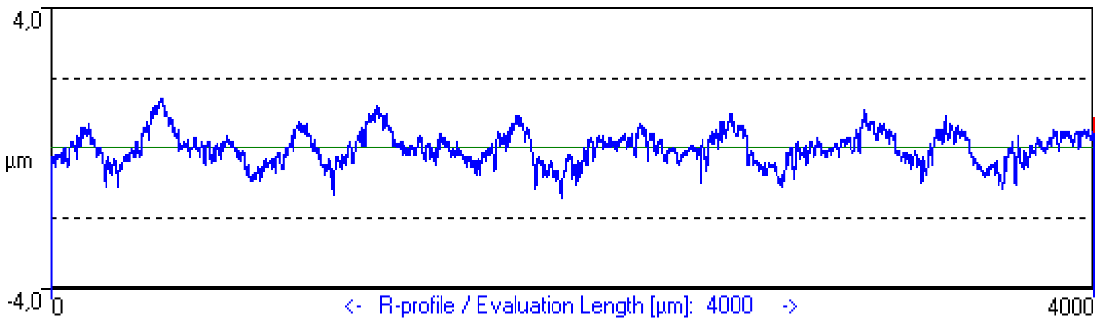
File: R2_100%   Profile no.: 3   Specimenmark: 0393341   03-05-2010



Ra 0,650
Rz 3,666

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: R2_100%   Profile no.: 4   Specimenmark: 0393341   03-05-2010

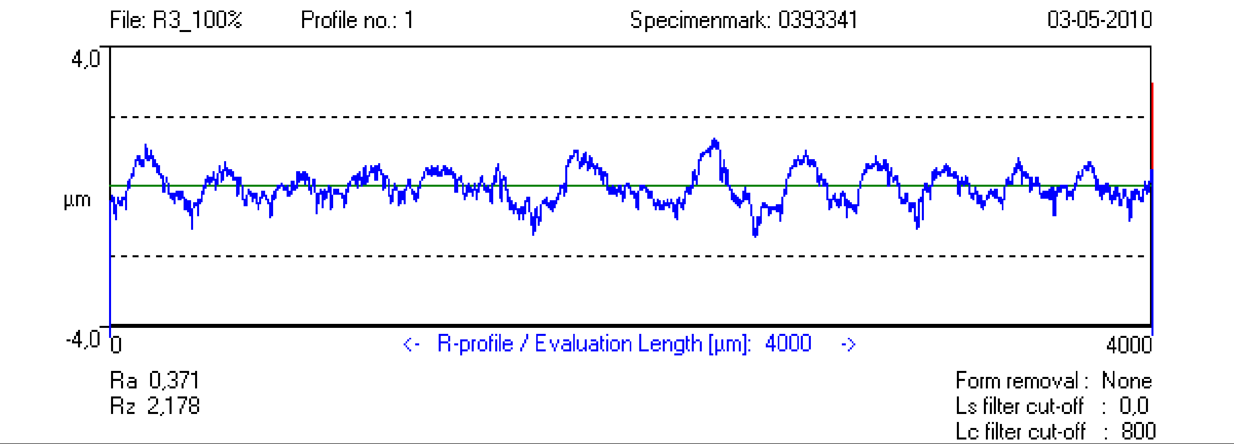


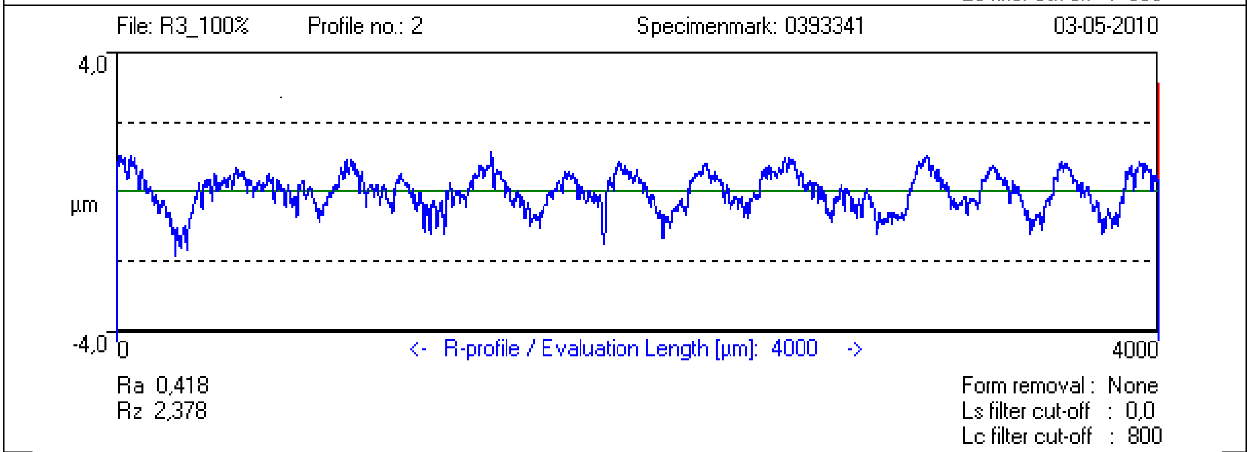
Ra 0,366
Rz 2,336

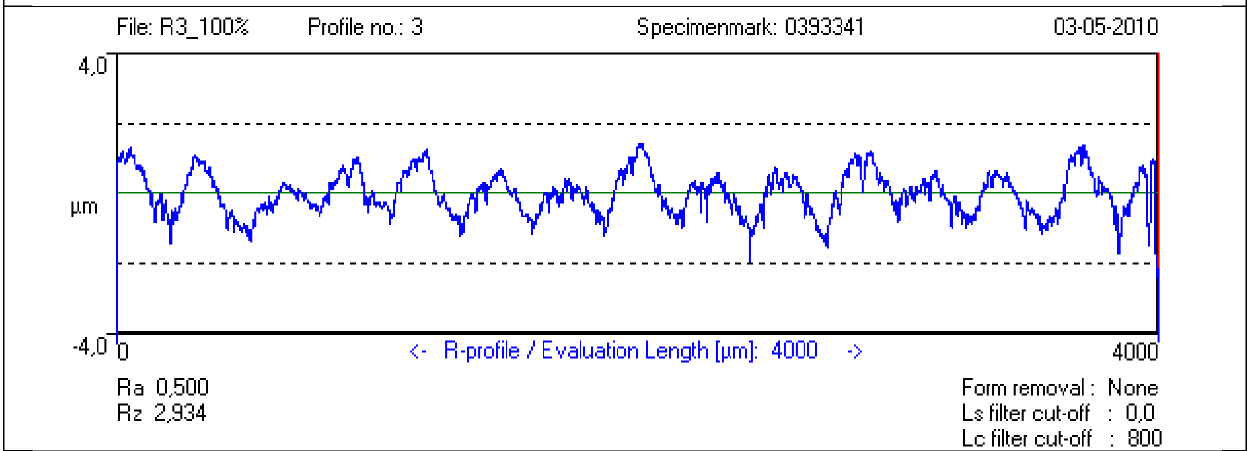
Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

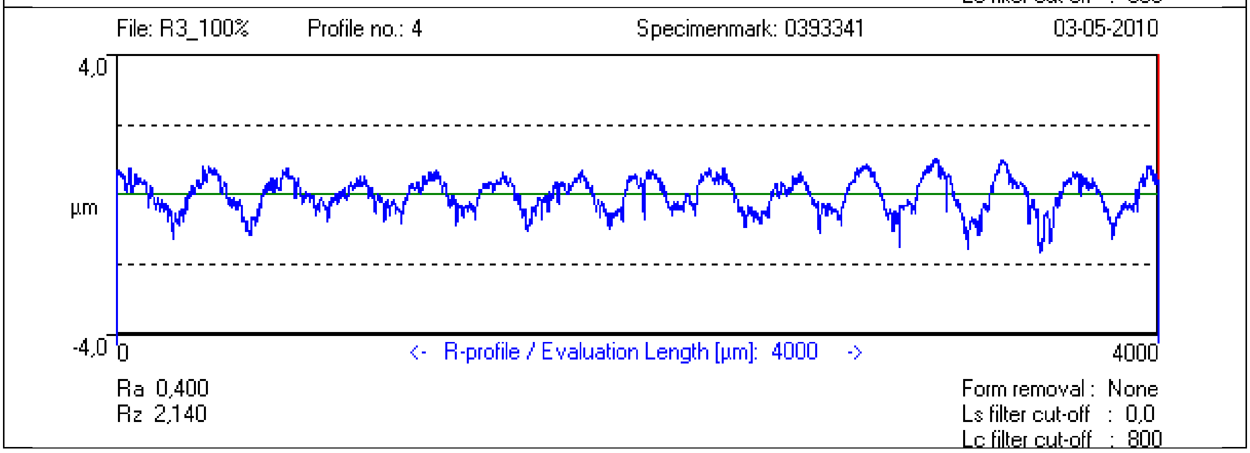
Operator D – 03/05 – 2010; P (low vc=4,5 m/min), R (high vc=10,2 m/min)

Workpiece R3 – OIL (R0.3/M)









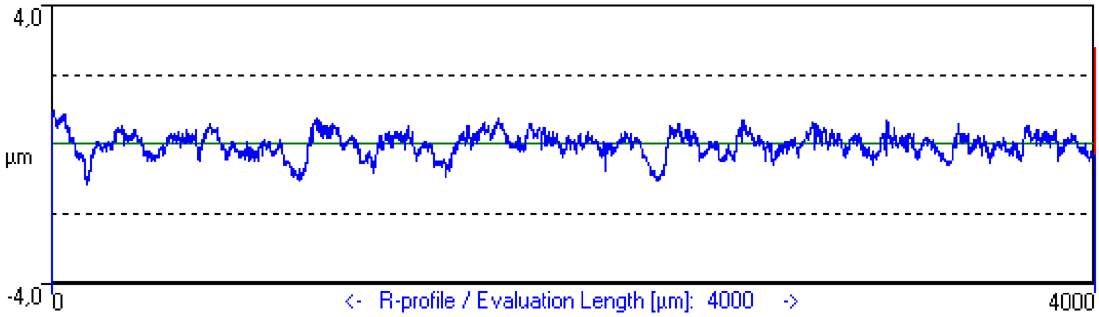
Appendix J6: Surface roughness measurement

Operator F: 22/6-2010

Operator F – 22/06 – 2010; P (low vc=4,5 m/min)

Workpiece P1 - neat oil (P0.3/N)

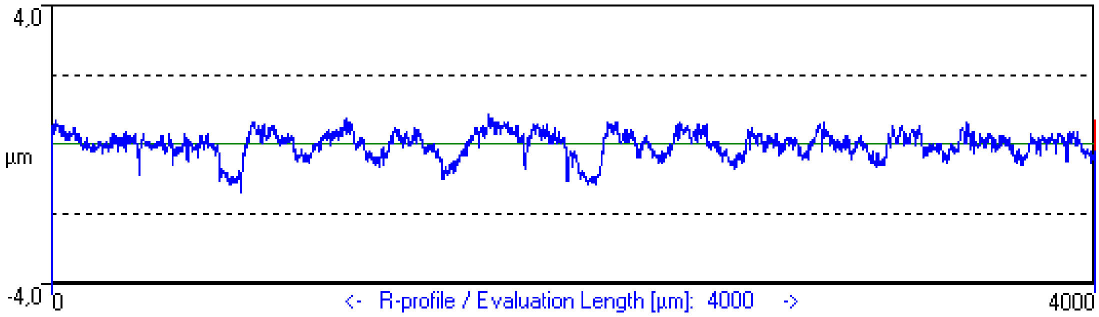
File: P1_TDN81_0.3.dat Profile no.: 1 Specimenmark: 0393341 23-06-2010



Ra 0,254
Rz 1,660
Rzmax 2,120

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

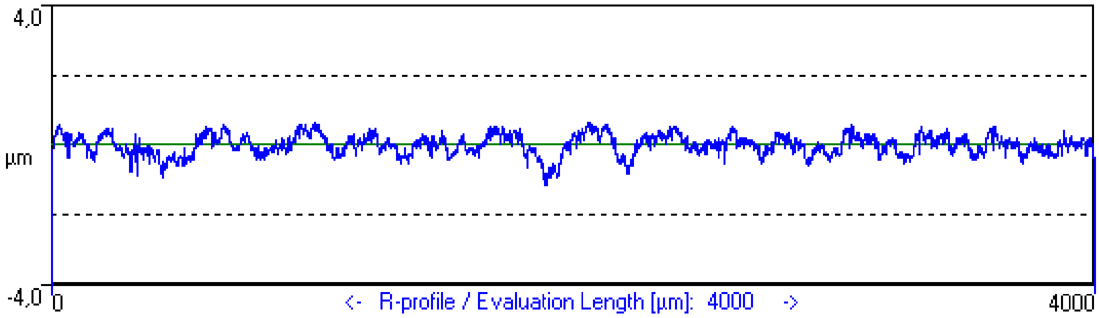
File: P1_TDN81_0.3.dat Profile no.: 2 Specimenmark: 0393341 23-06-2010



Ra 0,275
Rz 1,666
Rzmax 2,060

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

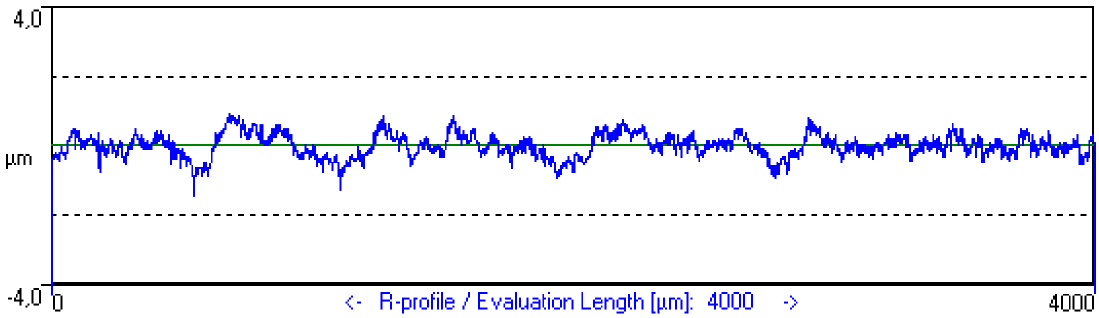
File: P1_TDN81_0.3.dat Profile no.: 3 Specimenmark: 0393341 23-06-2010



Ra 0,231
Rz 1,420
Rzmax 1,890

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: P1_TDN81_0.3.dat Profile no.: 4 Specimenmark: 0393341 23-06-2010



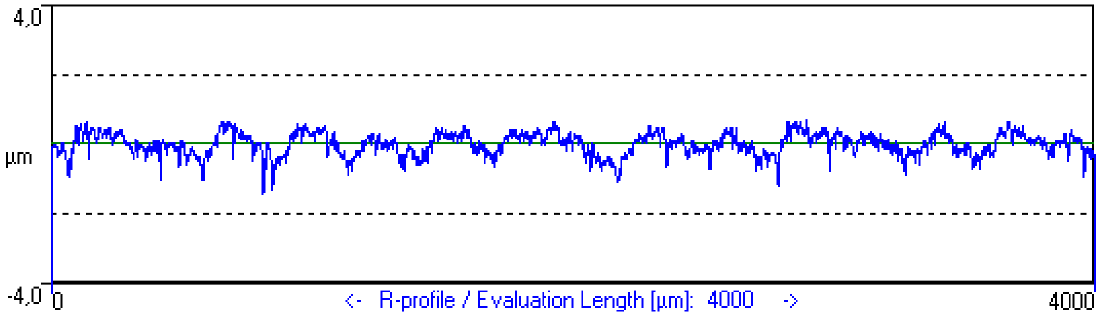
Ra 0,259
Rz 1,826
Rzmax 2,370

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator F – 22/06 – 2010; P (low vc=4,5 m/min)

Workpiece P2 - neat oil (P0.3/N)

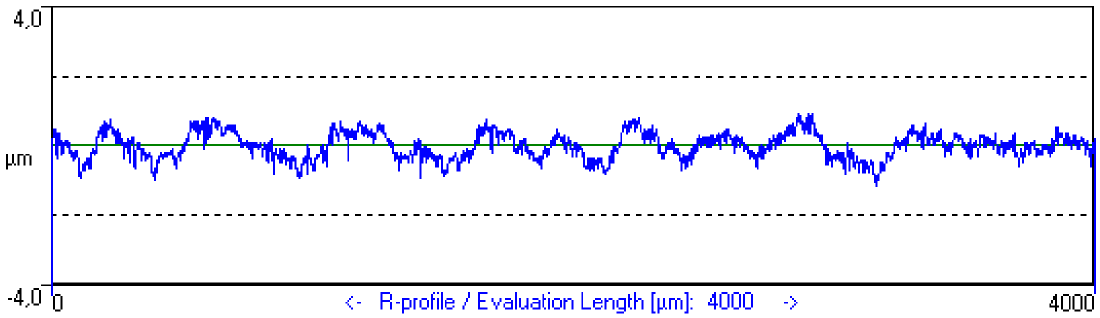
File: P2_TDN81_0.3 Profile no.: 1 Specimenmark: 0393341 23-06-2010



Ra 0,261
Rz 1,784
Rzmax 2,020

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

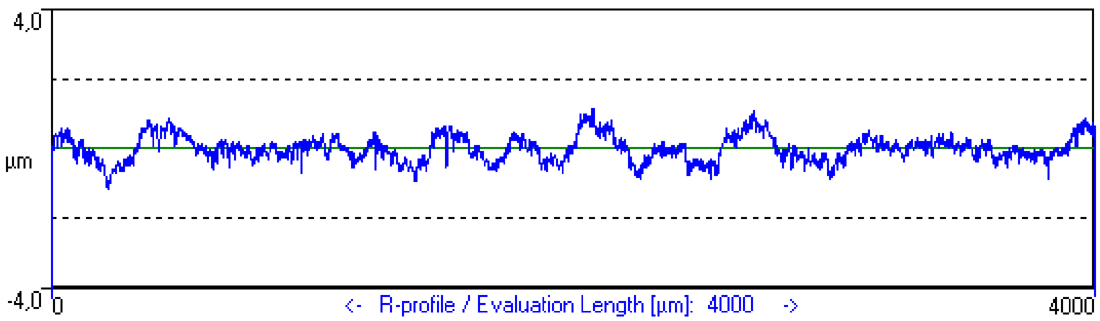
File: P2_TDN81_0.3 Profile no.: 2 Specimenmark: 0393341 23-06-2010



Ra 0,302
Rz 1,664
Rzmax 2,120

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

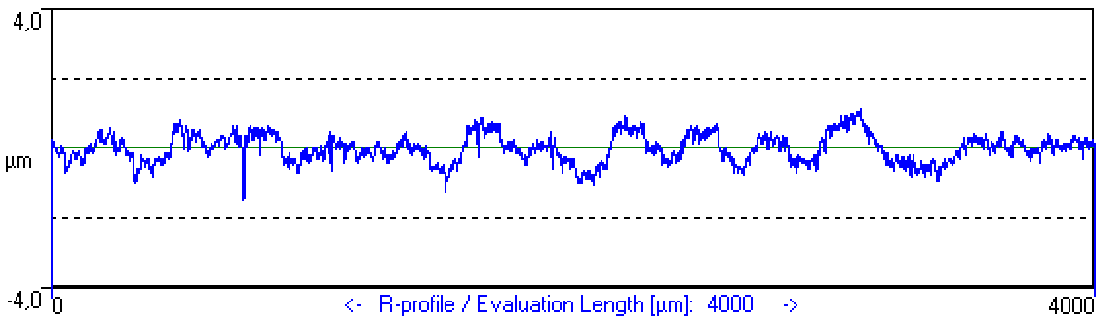
File: P2_TDN81_0.3 Profile no.: 3 Specimenmark: 0393341 23-06-2010



Ra 0,290
Rz 1,860
Rzmax 2,030

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: P2_TDN81_0.3 Profile no.: 4 Specimenmark: 0393341 23-06-2010



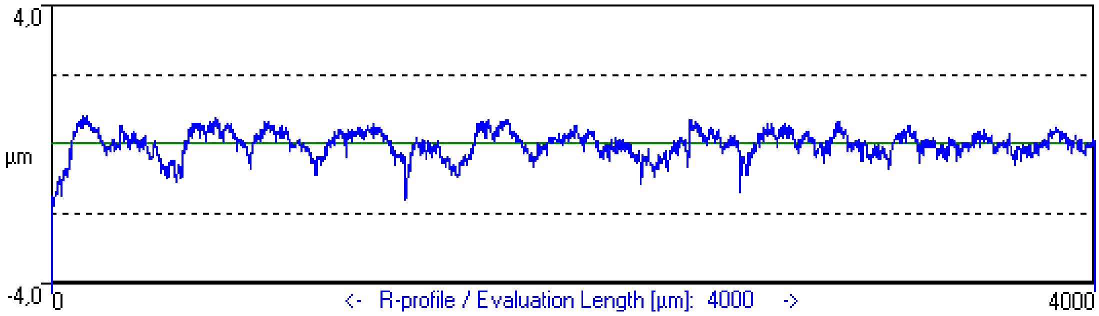
Ra 0,326
Rz 1,890
Rzmax 2,340

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator F – 22/06 – 2010; P (low vc=4,5 m/min)

Workpiece P3 - neat oil (P0.3/N)

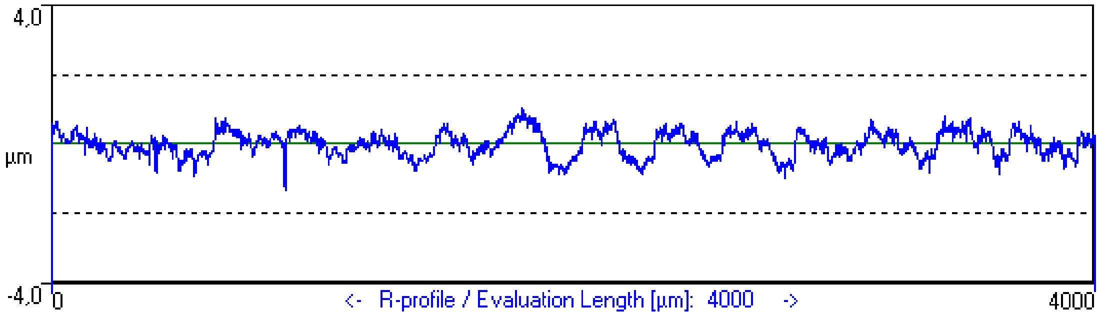
File: P3_TDN81_03 Profile no.: 1 Specimenmark: 0393341 23-06-2010



Ra 0,286
Rz 1,984
Rzmax 2,550

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

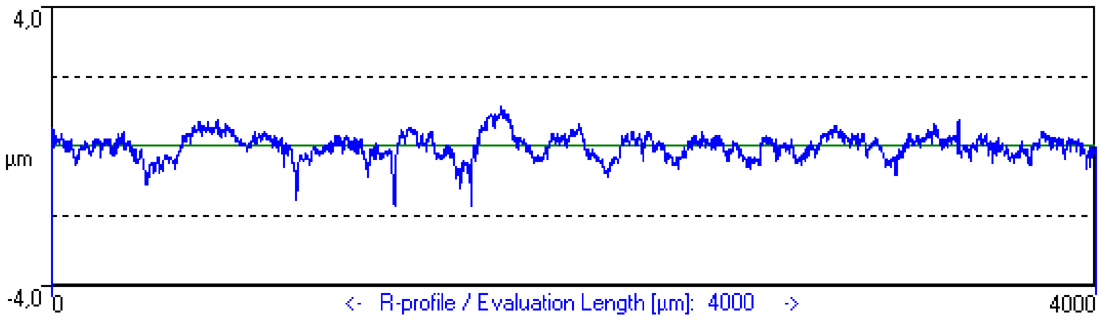
File: P3_TDN81_03 Profile no.: 2 Specimenmark: 0393341 23-06-2010



Ra 0,294
Rz 1,748
Rzmax 1,920

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

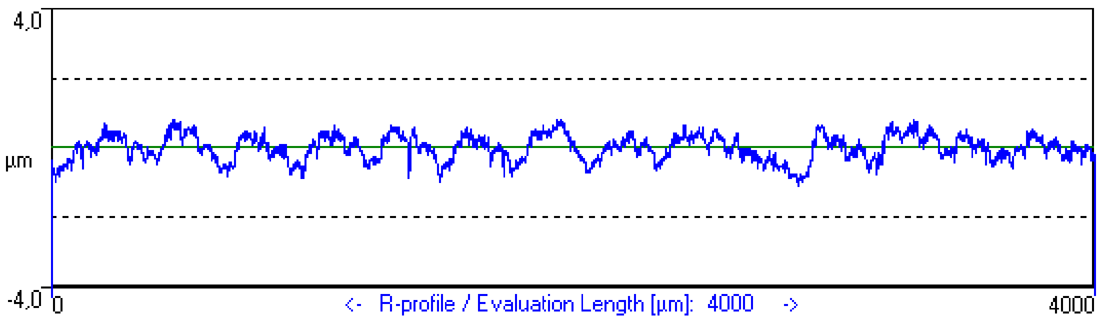
File: P3_TDN81_03 Profile no.: 3 Specimenmark: 0393341 23-06-2010



Ra 0,263
Rz 1,948
Rzmax 2,850

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: P3_TDN81_03 Profile no.: 4 Specimenmark: 0393341 23-06-2010



Ra 0,299
Rz 1,640
Rzmax 1,810

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

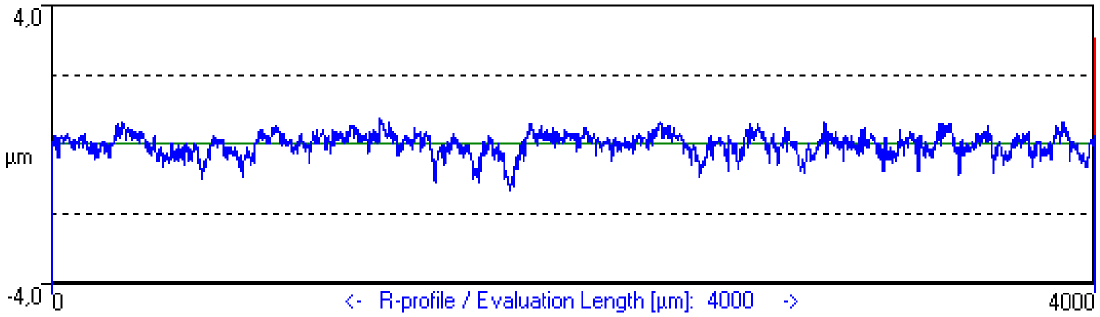
Appendix J7: Surface roughness measurement

Operator G: 22/6-2010

Operator G – 22/06 – 2010; P (low vc=4,5 m/min)

Workpiece P1 - neat oil (P0.2/N)

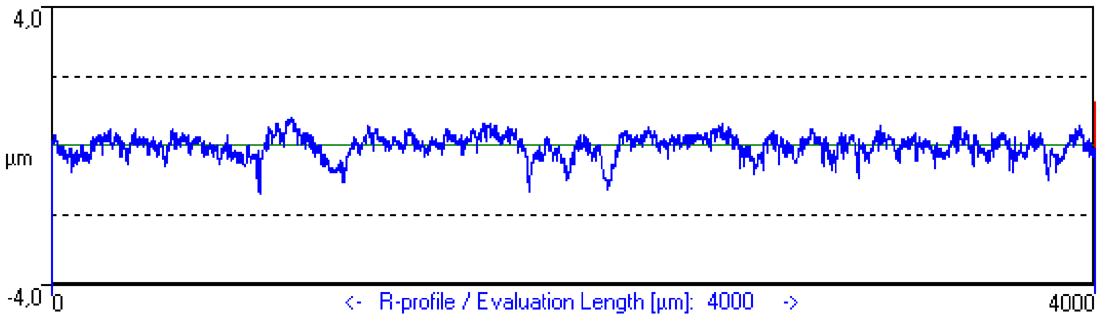
File: P1_TDN81_02 Profile no.: 1 Specimenmark: 0393341 23-06-2010



Ra 0,235
Rz 1,686
Rzmax 1,940

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

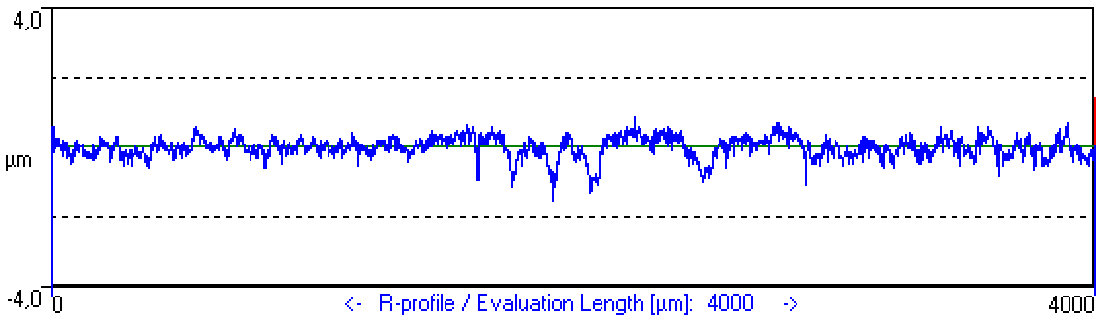
File: P1_TDN81_02 Profile no.: 2 Specimenmark: 0393341 23-06-2010



Ra 0,245
Rz 1,804
Rzmax 2,040

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

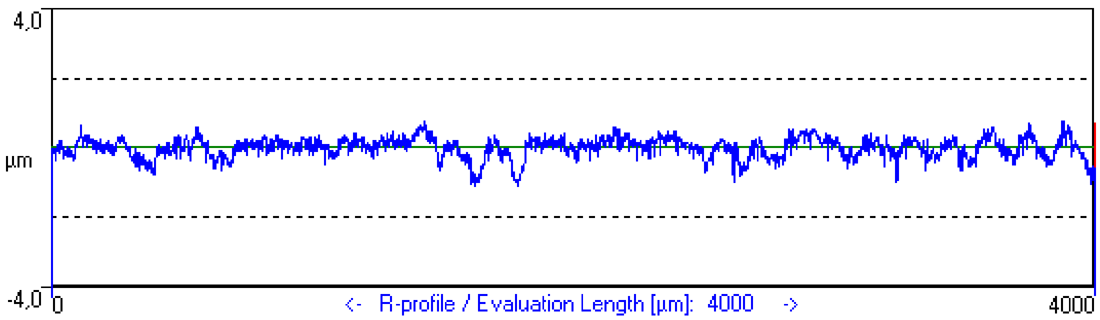
File: P1_TDN81_02 Profile no.: 3 Specimenmark: 0393341 23-06-2010



Ra 0,224
Rz 1,624
Rzmax 2,420

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: P1_TDN81_02 Profile no.: 4 Specimenmark: 0393341 23-06-2010



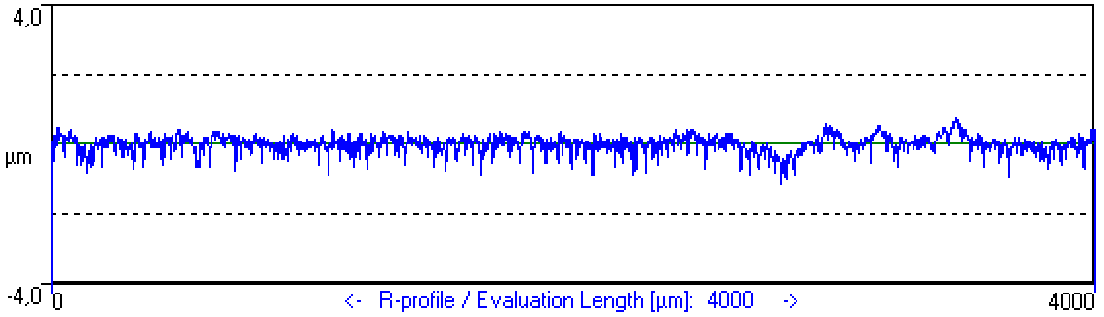
Ra 0,227
Rz 1,548
Rzmax 1,790

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator G – 22/06 – 2010; P (low vc=4,5 m/min)

Workpiece P2 - neat oil (P0.2/N)

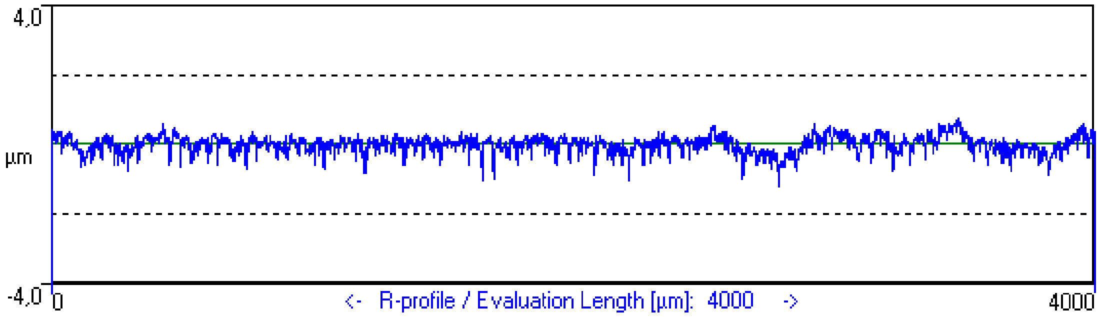
File: P2_TDN81_02 Profile no.: 1 Specimenmark: 0393341 23-06-2010



Ra 0,174
Rz 1,438
Rzmax 1,680

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

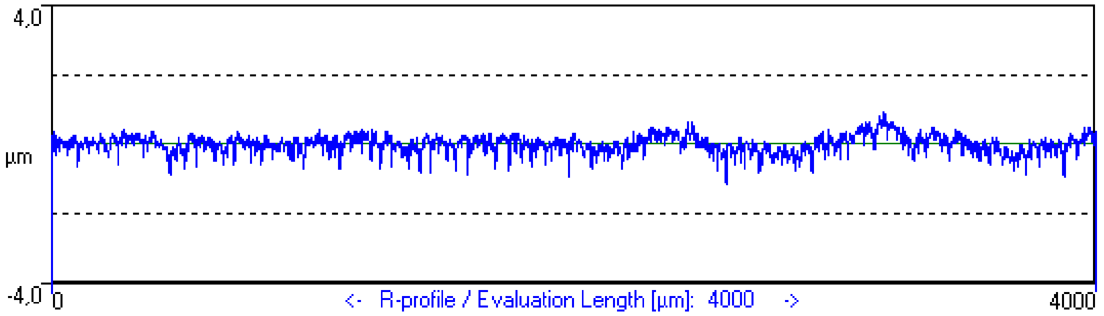
File: P2_TDN81_02 Profile no.: 2 Specimenmark: 0393341 23-06-2010



Ra 0,183
Rz 1,460
Rzmax 1,810

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

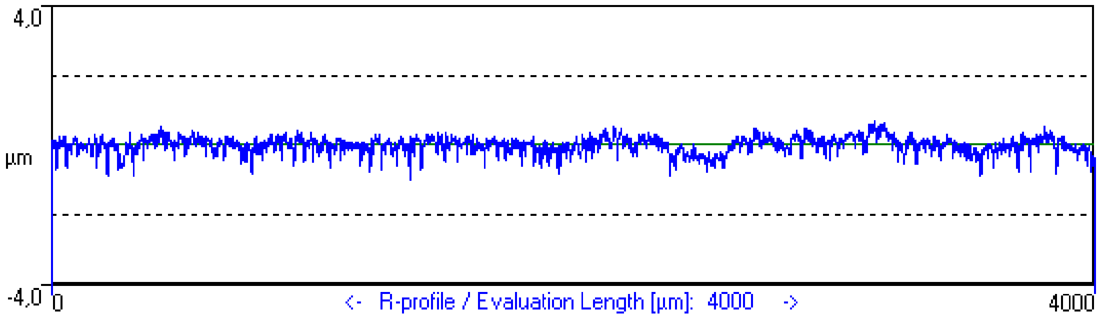
File: P2_TDN81_02 Profile no.: 3 Specimenmark: 0393341 23-06-2010



Ra 0,186
Rz 1,520
Rzmax 2,060

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: P2_TDN81_02 Profile no.: 4 Specimenmark: 0393341 23-06-2010



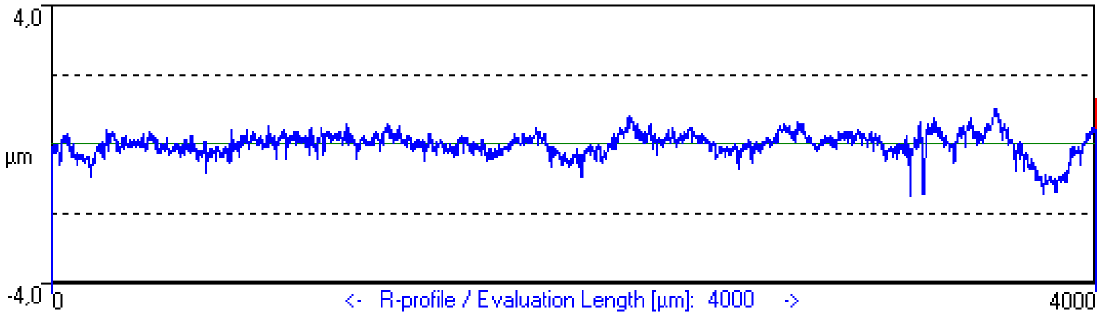
Ra 0,176
Rz 1,398
Rzmax 1,460

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

Operator G – 22/06 – 2010; P (low vc=4,5 m/min)

Workpiece P3 - neat oil (P0.2/N)

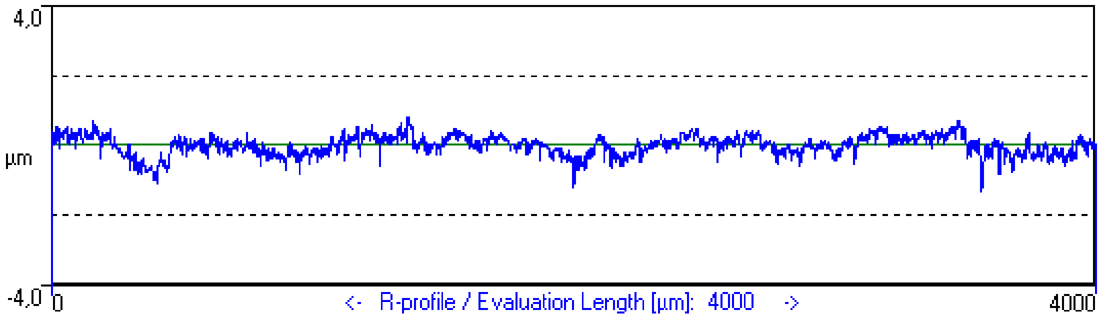
File: P3_TDN81_02 Profile no.: 1 Specimenmark: 0393341 23-06-2010



Ra 0,247
Rz 1,594
Rzmax 2,490

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

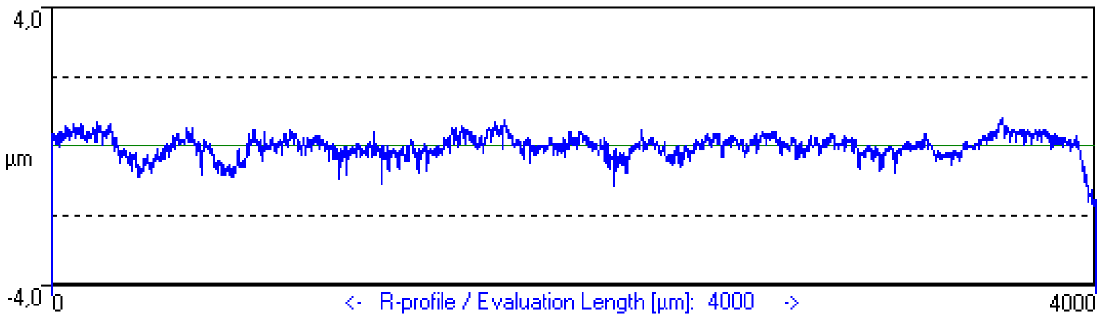
File: P3_TDN81_02 Profile no.: 2 Specimenmark: 0393341 23-06-2010



Ra 0,227
Rz 1,636
Rzmax 2,020

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

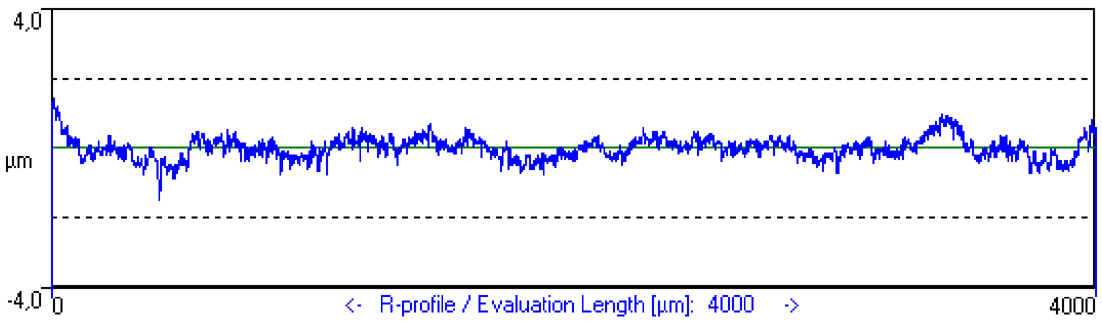
File: P3_TDN81_02 Profile no.: 3 Specimenmark: 0393341 23-06-2010



Ra 0,241
Rz 1,774
Rzmax 2,580

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800

File: P3_TDN81_02 Profile no.: 4 Specimenmark: 0393341 23-06-2010



Ra 0,240
Rz 1,698
Rzmax 2,870

Form removal : None
Ls filter cut-off : 0,0
Lc filter cut-off : 800